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Western Mining in the Twentieth Century Oral History Series

John J. Reed

PIONEER IN APPLIED ROCK MECHANICS, BRADEN MINE, CHILE, 1944-1950; ST. JOSEPH LEAD COMPANY, 1955-1960; COLORADO SCHOOL OF MINES, 1960-1972

With an Introduction by
Robert K. Barcus

Interviews Conducted by
Eleanor Swent
in 1991

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John J. Reed, circa 1985

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Introduction by Robert K. Barcus, vice president, retired, Cominco American, Inc.

Interview conducted in 1991 by Eleanor Swent for Western Mining in the Twentieth Century Oral History Series. The Regional Oral History Office, The Bancroft Library, University of California, Berkeley.

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PREFACE

The oral history series on Western Mining in the Twentieth Century documents the lives of leaders in mining, metallurgy, geology, education in the earth and materials sciences, mining law, and the pertinent government bodies. The field includes metal, non-metal, and industrial minerals, but not petroleum.

Mining has changed greatly in this century: in the technology and technical education; in the organization of corporations; in the perception of the national strategic importance of minerals; in the labor movement; and in consideration of health and environmental effects of mining.

The idea of an oral history series to document these developments in twentieth century mining had been on the drawing board of the Regional Oral History Office for more than twenty years. The project finally got underway on January 25, 1986, when Mrs. Willa Baum, Mr. and Mrs. Philip Bradley, Professor and Mrs. Douglas Fuerstenau, Mr. and Mrs. Clifford Heimbucher, Mrs. Donald McLaughlin, and Mr. and Mrs. Langan Swent met at the Swent home to plan the project, and Professor Fuerstenau agreed to serve as Principal Investigator.

An advisory committee was selected which included representatives from the materials science and mineral engineering faculty and a professor of history of science at the University of California at Berkeley; a professor emeritus of history from the California Institute of Technology; and executives of mining companies.

We note with much regret the death of two members of the original advisory committee, both of whom were very much interested in the project. Rodman Paul, Professor Emeritus of History, California Institute of Technology, sent a hand-written note of encouragement just a few weeks before his death from cancer. Charles Meyer, Professor Emeritus of Geology, University of California at Berkeley, was not only an advisor but was also on the list of people to be interviewed, because of the significance of his recognition of the importance of plate tectonics in the genesis of copper deposits. His death in 1987 ended both roles.

Thanks are due to other members of the advisory committee who have helped in selecting interviewees, suggesting research topics, and raising funds.

Unfortunately, by the time the project was organized several of the original list of interviewees were no longer available and others were in failing health; therefore, arrangements for interviews were begun even without established funding.

The project was presented to the San Francisco section of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) on "Old-timers Night," March 10, 1986, when Philip Read Bradley, Jr., was the speaker. This section and the Southern California section provided initial funding and organizational sponsorship.

The Northern and Southern California sections of the Woman's Auxiliary to the AIME (WAAIME), the California Mining Association, and the Mining and Metallurgical Society of America (MMSA) were early supporters. Several alumni of the University of California College of Engineering donated in response to a letter from Professor James Evans, the chairman of the Department of Materials Science and Mineral Engineering. Other individual and corporate donors are listed in the volumes. The project is ongoing, and funds continue to be sought.

Some members of the AIME, WAAIME, and MMSA have been particularly helpful: Ray Beebe, Katherine Bradley, Henry Colen, Ward Downey, David Huggins, John Kiely, Noel Kirshenbaum, and Cole McFarland.

The first five interviewees were all born in 1904 or earlier. Horace Albright, mining lawyer and president of United States Potash Company, was ninety-six years old when interviewed. Although brief, this interview will add another dimension to the many publications about a man known primarily as a conservationist.

James Boyd was director of the industry division of the military government of Germany after World War II, director of the U.S. Bureau of Mines, dean of the Colorado School of Mines, vice president of Kennecott Copper Corporation, president of Copper Range, and executive director of the National Commission on Materials Policy. He had reviewed the transcript of his lengthy oral history just before his death in November, 1987. In 1990, he was inducted into the National Mining Hall of Fame, Leadville, Colorado.

Philip Bradley, Jr., mining engineer, was a member of the California Mining Board for thirty-two years, most of them as chairman. He also founded the parent organization of the California Mining Association, as well as the Western Governors Mining Advisory Council. His uncle, Frederick Worthen Bradley, who figures in the oral history, was in the first group inducted into the National Mining Hall of Fame, Leadville, Colorado, in 1988.

Frank McQuiston, metallurgist, vice president of Newmont Mining Corporation, died before his oral history was complete; thirteen hours of taped interviews with him were supplemented by three hours with his friend and associate, Robert Shoemaker.

Gordon Oakeshott, geologist, was president of the National Association of Geology Teachers and chief of the California Division of Mines and Geology.

These oral histories establish the framework for the series; subsequent oral histories amplify the basic themes.

Future researchers will turn to these oral histories to learn how decisions were made which led to changes in mining engineering education, corporate structures, and technology, as well as public policy regarding minerals. In addition, the interviews stimulate the deposit, by interviewees and others, of a number of documents, photographs, memoirs, and other materials related to twentieth century mining in the West. This collection is being added to The Bancroft Library's extensive holdings.

The Regional Oral History Office is under the direction of Willa Baum, division head, and under the administrative direction of The Bancroft Library.

Interviews were conducted by Malca Chall and Eleanor Swent.

Willa K. Baum, Division Head
Regional Oral History Office

Eleanor Swent, Project Director
Western Mining in the Twentieth
Century Series

October 1990
Regional Oral History Office
University of California, Berkeley

Western Mining in the Twentieth Century Oral History Series
Interviews Completed, January 1993

Horace Albright, Mining Lawyer and Executive, U.S. Potash Company, U.S. Borax, 1933-1962, 1989

Samuel S. Arentz, Jr., Mining Engineer, Consultant, and Entrepreneur in Nevada and Utah, 1934-1992, 1993

James Boyd, Minerals and Critical Materials Management: Military and Government Administrator and Mining Executive, 1941-1987, 1988

Philip Read Bradley, Jr., A Mining Engineer in Alaska, Canada, the Western United States, Latin America, and Southeast Asia, 1988

Catherine C. Campbell, Ian and Catherine Campbell, Geologists: Teaching, Government Service, Editing, 1989

James T. Curry, Sr., Metallurgist for Empire Star Mine and Newmont Exploration, 1932-1955; Plant Manager for Calaveras Cement Company, 1956-1975, 1990

J. Ward Downey, Mining and Construction Engineer, Industrial Management Consultant, 1936 to the 1990s, 1992

Hedley S. "Pete" Fowler, Mining Engineer in the Americas, India, and Africa, 1933-1983, 1992

James Mack Gerstley, Executive, U.S. Borax & Chemical Corporation; Trustee, Pomona College; Civic Leader, San Francisco Asian Art Museum, 1991

John F. Havard, Mining Engineer and Executive, 1935-1981, 1992

George Heikes, Mining Geologist on Four Continents, 1924-1974, 1992

Helen R. Henshaw, Recollections of Life with Paul Henshaw: Latin America, Homestake Mining Company, 1988

Lewis L. Huelsdonk, Manager of Gold and Chrome Mines, Spokesman for Gold Mining, 1935-1974, 1988

Arthur I. Johnson, Mining and Metallurgical Engineer in the Black Hills: Pegmatites and Rare Minerals, 1922 to the 1990s, 1990

Evan Just, Geologist: Engineering and Mining Journal, Marshall Plan, Cyprus Mines Corporation, and Stanford University, 1922-1980, 1989

Plato Malozemoff, A Life in Mining: Siberia to Chairman of Newmont Mining Corporation, 1909-1985, 1990

James and Malcolm McPherson, Brothers in Mining, 1992

Frank Woods McQuiston, Jr., Metallurgist for Newmont Mining Corporation and U.S. Atomic Energy Commission, 1934-1982, 1989

Gordon B. Oakeshott, The California Division of Mines and Geology, 1948-1974, 1988

Vincent D. Perry, A Half Century as Mining and Exploration Geologist with the Anaconda Company, 1991

Carl Randolph, Research Manager to President, U.S. Borax & Chemical Corporation, 1957-1986, 1992

John Reed, Pioneer in Applied Rock Mechanics, Braden Mine, Chile, 1944-1950; St.Joseph Lead Company, 1955-1960; Colorado School of Mines, 1960-1972, 1993

Joseph Rosenblatt, EIMCO, Pioneer in Underground Mining Machinery and Process Equipment, 1926-1963, 1992

Eugene David Smith, Working on the Twenty-Mule Team; Laborer to Vice President, U.S. Borax & Chemical Corporation, 1941-1989, 1993

James V. Thompson, Mining and Metallurgical Engineer; the Philippine Islands; Dorr, Humphreys, Kaiser Engineers Companies; 1940-1990s, 1992

Interviews In Process

Donald Dickey (Oriental Mine), in process

James Jensen (metallurgy), in process

Robert Kendall (U.S. Borax), in process

John Livermore (geologist), in process

Langan Swent (San Luis, Homestake, uranium mining), in process

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BIOGRAPHICAL INFORMATION

(Please write clearly. Use black ink.)

Your full name John Joseph Reed

Date of birth June 18, 1923 Birthplace Los Angeles, Calif.

Father's full name James Wallace Reed

Occupation Diamond Driller Birthplace Goderich, Ontario, Ca.

Mother's full name Jane Cecelia Francis — Reed

Occupation Homemaker Birthplace Greenland, Mich.

Your spouse 1. Eileen Butler (1946-1969), 2. Beverly Phillips (1974 -)

Your children John P, Robert M., Georgia A, Patricia E.

Where did you grow up? Los Angeles

Present community Anacortes, Wash.

Education Fairfax H.S., U.C.L.A., → Berkeley U.C, B.S. 1944, M.S. 1952, Ph.D. 1955; all in Mining Engineering

Occupation(s) Mining operations, hydro-electric & underground construction, Mining Research Engr., Mining Consultant

Areas of expertise Applied Rock Mechanics = Underground Excavation & Rock Reinforcement, Design & Construction of Large U.G. Openings, Mine Ventilation

Other interests or activities Sailing, travel, expedition or survival food. Am an "inveterate tinkerer" or compulsive inventer of tools & gadgets.

Organizations in which you are active? AIME-SME, Local Citizens Group to "watch-dog" City Hall re: sewage treatment, Park Lands Development, etc.

INTRODUCTION--by Robert K. Barcus

John Reed was a doctoral candidate and instructor in mining engineering at UC Berkeley when I was an undergraduate mining engineer. I first met him in 1951 as a student in one of his classes, and even then he was clearly a gifted teacher. I was in my mid-twenties and a grizzled veteran of the GI Bill, but I often refer to him as my Old Professor although he is in fact a few months younger than I.

There were only five of us in mining engineering in the class of 1952, so the atmosphere in the mining classes was quite informal. We students formed lifelong friendships with one another and with our teachers and professors. John invited us to his home more than once for dessert and conversation and to view his slides of Chile and the Braden mine where he had worked.

His experiences in that great mine were intensely interesting to those of us who were looking forward to jobs in mines after graduation. The slides showed us that he had once been an avid outdoor sportsman, fishing in the Chilean lakes and rivers, hunting birds in the mountains, and skiing the Andean snow fields. By the time I met him, such activities had been largely denied him by severe crippling polio.

Instead of mourning his misfortune, he had determined to earn the first Ph.D. ever awarded at Berkeley in mining engineering and was pursuing that goal with the same combination of iron will, good humor, and common sense that he applied to personal and professional matters throughout his life.

I was gone from Berkeley by the time he got his Ph.D. but I saw him regularly in the years afterward at St. Joe Lead Company in Missouri where he founded the mining research department that became famous in an industry not noted for innovation, and later at the Colorado School of Mines in Golden where he became head of the mining engineering department.

After he left Golden, my company employed him for several years as a consultant at a major mine in Missouri. He was particularly effective in that difficult role because he was able to combine a high level of scientific expertise with practical solutions and recommendations that were understandable and usable by our miners and mine supervisors in the harsh environment where they worked.

Because of his early career in mine production, he knew that fragile devices or complex procedures that might work in a laboratory would not survive in the mine. He insisted that new and unfamiliar equipment for the miners be as rugged and simple as possible. New mining procedures of

his design had to be understood and accepted not just by the management who hired him but by the miners and their supervisors who would put them into practice. In my experience with consultants in other fields, I found such a sensible concern for all levels of a client's organization to be nearly unique.

He is an enthusiastic sailor, and for several years was the despotic master of the "Heilan' Lassie," a seagoing twenty-five-foot ketch. For three weeks in 1975, his wife, his brother Jim, and I were crew on an epic 1,400-mile voyage in the "Lassie" from Long Beach down the length of Baja California and up the Sea of Cortez to Guaymas. Those weeks before the mast under his command remain one of the truly memorable experiences of my life.

He is retired now to a hillside home with a sweeping view of the beautiful San Juan Islands north of Seattle. I contact the Old Professor from time to time, and when he's not travelling I usually find him involved with some new project that incorporates his twin principles of scientific investigation and practicality. His whimsical Frugal MacDougall Industries (very) Ltd., through which these projects are promoted, reflects both his proud Scottish heritage and his wry sense of humor, as well as his constant search for better ways to do things.

Robert K. Barcus
Vice President (retired)
Cominco American, Inc.

November 1991
Spokane, Washington

INTERVIEW HISTORY--by Eleanor Swent

John Reed was recommended for the series on Western Mining in the Twentieth Century because of his varied and influential career as practical mining engineer, research scientist in rock mechanics, and professor of mining. He graduated from the University of California College of Mining at Berkeley in 1944, and went to work for Braden Copper Company, a Kennecott subsidiary, in Chile. He was a mine shift boss there at El Teniente Mine in June 1945 when the most disastrous metal mine fire in history took 354 lives; in his oral history he discusses the fire in detail.

He became assistant mine foreman, but had to return to the United States in 1950 when he became severely ill with poliomyelitis. The experiences of the mine disaster and disabling illness influenced his subsequent career in which he has improved underground safety around the world through his work as teacher, lecturer, and consultant. He has raised mining engineering to a science with emphasis on the recognition of the rock which surrounds underground excavations as a structural material to be reinforced and stabilized for safety and efficiency.

After a rehabilitation program with Dr. Charles Lowman in Los Angeles, John Reed earned M.S. and Ph.D. degrees in rock mechanics at UC Berkeley and developed a packaged stench warning system for mines. From 1955 to 1960 he was head research engineer for St. Joseph Lead Company in Missouri, doing pioneering work in rock bolting and precise instrumentation of rock deformation. He advanced the use of flat jacks in pre-loaded concrete pillars, deep drill rounds in dolomite, grouting and grout valves. He developed some safety devices commercially through business ventures.

From 1960 to 1972, he was professor of mining at Colorado School of Mines; he retired as chairman of the mining department. He has been a consultant to the Corps of Engineers, NORAD [North American Air Defense Command], US Bureau of Reclamation, and the South African Chamber of Mines, and he has advised on such diverse projects as the Manhattan aqueduct, underground powerhouses, and nuclear waste storage.

John Reed readily refers to himself as handicapped, but within a minute of meeting him, I was so charmed by his friendliness and energy that the handicap was forgotten. He is tall, thin, and fit looking. He cannot use stairs, but can drive his van, in spite of somewhat limited use of his hands. He is much interested in health and nutrition, and freely dispenses stone-ground grains and delicious mixtures of dried fruit. One of his pleasures is developing better kinds of trail mix and foods for campers, which he markets under the name Frugal McDougall. He evidences some irritation, but no bitterness, over the lack of

understanding shown by his employer and others after he contracted polio. His subsequent outstanding career has been a triumph over this early setback, and he is an exceptionally warm and sympathetic person.

The Reeds now live in Anacortes, Washington. He drove to Berkeley for the interviews and was the houseguest of Professor Neville Cook and his wife Jennifer. Following a planning session, interviews were conducted at the Regional Oral History Office on 21, 22, 23, and 25 March, 1991. The lightly edited transcript was sent to him for review and returned after he made many minor changes in diction, and added some factual detail.

The introduction was written by an associate and friend, Robert K. Barcus, vice president (retired) of Cominco American Inc.

The tapes of the interview are available for study at The Bancroft Library, University of California at Berkeley.

Eleanor Swent, Project Director
Western Mining in the Twentieth
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I EARLY YEARS AND FAMILY

[Interview 1: March 21, 1991]##

Swent: Let's start at the beginning. Do you want to tell when and where you were born, and something about your family?

Reed: I was born in Los Angeles in 1923. My mother was born and raised in the iron and copper mining country of Upper Michigan. Her two grandfathers (my great-grandfathers) were both copper miners, perhaps at the Victoria Mine near Ontonagon. One, Joseph Dubuque, was born in 1824 near Montreal and hiked down to Michigan at the age of thirteen to become a miner. In 1864 he married Agnes MacLachlan, who had come over alone from Scotland in 1852 at age seventeen to join an older sister married to Henry Buzzo, a Cornish mine captain at the Victoria Mine. Agnes finished her journey to Ontonagon in a canoe on Lake Superior, paddled by an Indian.

The other grandfather was John Francis, a "Cousin Jack" miner from Cornwall. His son, Paul, was a logger who supplied the heavy timbers to the mines. Paul also became the youngest sheriff ever elected in Ontonagon County.

Thus my name, John Joseph, comes down from two great-grandfathers, both early copper miners in Upper Michigan (and who knows how much farther back in Cornwall). Not surprisingly, I have been an enthusiastic consumer, critic, and promoter of "Cousin Jack pasties" since boyhood!

My mother, Jennie Francis, studied at the State Normal School in Marquette and was teaching school in or around Greenland, Michigan, when she met and married my father in 1913. She is mentioned in the book The Sword and the Gavel, by William Wilkins, judge at the Nuremberg trials, who also grew up in Greenland at that time.

Father, James Wallace Reed

A Diamond Drill Runner for E. J. Longyear

Reed: My father was born in Canada in Goderich, Ontario, but his mother took him when he was just a baby to Duluth, so he grew up there. When he was about sixteen, at the end of eighth grade, he got a job on a diamond drill and started drilling in the [Minnesota] Iron Range. He was born in '85, and by the time he was about nineteen or twenty, he was looking for other places or--I don't know, he had been working for E. J. Longyear, a well-known company. I have a letter of recommendation written April 25, 1904, by E. J. Longyear, saying that my dad was a competent runner and a serious young man, and so forth. I think this was probably written to him when he went from Hibbing, Minnesota, to Bisbee, Arizona, to drill.

Swent: It said he was a competent runner?

Reed: Yes. There are two men who run a diamond drill. One is the runner--he's the boss--and a helper; it's a two-man crew. When he went to work, he was the helper. The runner was very responsible in those days. The diamond bit used only about six or seven diamonds. They were, of course, industrial diamonds, but they were big--almost as big as a pea--and they cost a lot of money; they could be a couple thousand dollars apiece. So that bit that was down at the end of the rods could be four or five or six thousand dollars worth, and the runner is responsible for not getting it burnt up or stuck or broken or whatever. So he has a responsible job, and they don't just let anybody be a runner; you have to demonstrate your ability.

The next step up from a runner--if you had several diamond drills, there would be a setter. He's the fellow who resets the bits. Every time the bit is run a while the diamonds tend to get worn flat. You take them out of the bit by dissolving the setting in acid. Then you turn the sharp edges up and re-set them in a new bit. That's pretty skilled work, too. So that's the hierarchy of diamond drilling, starting with the helper, then the runner, and then a setter, like a supervisor. I learned all that from my dad, so I've known the terms all my life.

Anyway, he went to Bisbee, Arizona, in 1904 and drilled there. I know he went into Mexico also, and I suspect it was to Cananea, the big copper mine there. At some time while he was in Mexico he got dysentery; things haven't changed. [laughter] We're talking 1905, I guess, and he ended up in the Los Angeles area to

recuperate in a hospital or whatever. Mind you, he grew up and worked in Minnesota, with bitter winters, so he took one look around at the green grass and the palm trees and everything, and he said, "When I've got a stake, this is where I'm going to retire." Well, it was a long time later, but that's why I ended up being born there.

He went up the coast, then, arriving in Hedley, B.C., in the fall of 1905. I have a picture of him at the Hedley Mine in British Columbia in 1906, and I know he drilled for coal in Alberta. But eventually he got back into Minnesota and Michigan.

Swent: Did he have his own rigs?

Reed: No, I doubt it. I think he was working for somebody else. I don't know who, probably somebody connected with E. J. Longyear.

A Drilling Contractor in Sudbury and Red Lake, Canada

Reed: Somewhere along the line he met my mother. She was teaching school in Greenland in Upper Michigan. They were married in 1913 and went, I think, to the Sudbury area in Canada to work, because my older brother was born in July 1914 at Creighton Mine, which is one of the mines of Sudbury. By about July 1915, Dad got to the level of being a contractor, and he set up shop in Timmins, Ontario, which is farther up north. It became Reed and Ryan Drilling Contractors. One other brother, Jim, was born down in Michigan at my mother's home, and a third brother, Bill, was born in Timmins.

The boys all grew up in Timmins until they were about five, six, and eight, and then finally in 1922 the family decided it was time to go to California. They got a big seven-passenger Marmon touring car in Duluth and drove across the country. In those days it was mostly gravel roads, and they got hauled out by a team of horses more than once, and things like that. They got to California, and that's why I came to be born there in 1923.

Swent: Was he still doing the same work?

Reed: His partner, I think, was trying to buy him out. In the winter of 1925-26, gold had been discovered at Red Lake, which is up north of Lake Superior in western Ontario. It's 175 miles north of Hudson on the railroad. Reed and Ryan got the contract to take the first drills there, so I have some very interesting old reports and

letters and so forth. I know Dad was up there in March 1926, when I was two years old.

Swent: He left the family in southern California while he went up there to work?

Reed: Right. At least that winter, to get the drills in there over the ice and before the breakup. Eventually he ended up in Los Angeles, bought land, and built a small two-story building with stores downstairs and apartments and offices upstairs. He gradually moved westward as the city grew, so he did very well in real estate from then on through the years.

A Partner in See's Candy

Swent: So he got out of the drilling business?

Reed: He really got out of the drilling business, yes. There is another interesting sidelight on this, and I think it is part of what actually precipitated the move down here. You know See's Candies, of course. Charlie See was a Canadian, apparently, or at least my father knew him in Canada. See worked for Laura Secord, which is the Canadian candy company. Incidentally, Dad built the first brick building in Timmins, Ontario; it's a three-story building at Third and Pine Streets, right on the main corner. That was, of course, when they were up there, long before me. I think perhaps there was a Laura Secord store in the building as one of the tenants.

At any rate, Charlie See told Dad he was going to Los Angeles, California, and start a candy factory, and he asked if Dad wanted to put up some capital and be partners. So the folks came down from Canada in 1922, and I think Dad put up eight thousand dollars to be Charlie's partner in See's Candies. After a year or two there were at least two stores, one downtown and one in Pasadena, but Dad became dissatisfied with the receipts and accounting. The best solution to the problems turned out to be the withdrawal of Dad's original investment and the dissolution of the partnership, and that's the way it worked out.

Swent: Every time you pass a See's Candy store, you'll think about it.

Reed: Yes, and you always see the ads with Grandma See sitting there in her rocking chair. I wonder about that!

Growing Up in the Wilshire District, Los Angeles

Reed: So that had something to do with Dad coming to California, but real estate investment became his thing, and it was a very good one. I got started with him--he put me to work as soon as I could help him. My junior high school was only a block or two from one of his buildings--his very first building--so my job after school was to walk down there a block or two and mop the upstairs floors and the stairs and sweep out and then go on home. I got a small recompense for that and earned spending money. Then as I got older he taught me to do the plumbing, the painting--I worked as an apprentice with a painter all one summer--and roofing. You name it around a building, and he taught me to do it. I made lots of spending money that way, and it saved him a lot of money; he didn't have to pay an expensive plumber. And I learned a lot, because he was handy with tools. Well, he had to be, with the work he had done.

Swent: He did all this with no advanced formal education?

Reed: No, eighth grade was as far as he ever went. He was half Scots, and his mother was very hard-working. She raised him on her own. I don't know, something happened between the parents when he was a baby, so I don't know anything about his father, William Reed. His mother was very proud of her Scottish heritage and was very industrious. She was a seamstress; she made dresses for people. She made money and invested it. She owned the building she lived in in Los Angeles--a business building with a Safeway store downstairs and offices and apartments upstairs.

Swent: This was your grandmother?

Reed: Yes. She did all that on her own as a single mother. She was a very hard-working, industrious, and thrifty person.

Swent: Wallace was her maiden name?

Reed: Actually, her maiden name was Agnes S. Baillie, but she was very proud of the Wallace in the family background. It was her mother's maiden name. At any rate, she made that her son's middle name.

Swent: Did you live right in Los Angeles?

Reed: Yes, in what you call the Wilshire district; it's kind of the western side. Now it's fairly near downtown, but it seemed like it was a long way west of downtown then. I guess it was three miles west of downtown. It's between Vermont and Western, and Third

Street and Beverly, if you know where that is. Second and Ardmore is where it was.

Swent: Does your family still have real estate in that neighborhood?

Reed: No, Mom sold the house about 1946. I visited the old house just a year or two ago. A relative had checked on it recently. I had driven by it several times, but it's become "Little Korea" around there now. I could never see anybody out in the yard, and I was hesitant about getting out and wandering around, so I hadn't done anything. A cousin, Carl Terry, who incidentally is the son of Emma Riddle-Terry, the family historian--I had forgotten that his parents were married in that house, so he had an interest in the house, too. He went there, and the man who is living there now is named Forbes Forbes. Strangely enough, he grew up just a couple of doors away in another house. His father was a dentist, and my brother Bill remembers going to him as a young man back from the war to get a tooth fixed. But I never knew the man.

He ended up buying it, not from my mother but a couple of owners later. He's been in that house for about thirty years, and now he's about ready to sell it. When I went there to visit, he was very interested. I spent a couple of hours there. The house had been enlarged and things had been changed, but he didn't know who did it. So I was able to fill him in on what was done when I was there, and that sort of thing, which was interesting. He said he was going to sell it for $300,000 or something, and it's an old bungalow, you know. I think my mother and dad probably paid $4,000 or $5,000 for it, and when my mother sold it in about 1946, I don't think she got more than $15,000 or $20,000. And now, imagine what it's worth, and it's still just an old frame--it's a nice old house, probably built in 1915 or something like that. The area is well kept; the lawns are taken care of, and the houses are cared for. It hasn't become a slum or anything. The school system in Los Angeles is less than half Anglo-Saxon now, and along Vermont and Third Street and Western, the shop signs are in Korean.

Swent: What high school did you go to?

Reed: Fairfax High School. Actually, I was in Belmont's district, which was downtown. I went to Virgil Junior High, which was on Vermont. I was supposed to go to Belmont High School. The street right behind us, Kingsley, was at that time the boundary, so I was one block out of the Fairfax district. But my father by this time had another building, and he was living at Beverly and Fairfax, which is right near Fairfax High School, about four miles west. I was to be his maintenance man, and I had a good argument for asking for special dispensation. So I went to school there, and after school

I'd go down to his building and maintain it. That's why I went to Fairfax High School.

Swent: Did you start studying science in high school?

Reed: Oh, yes. I knew what I wanted to be by that time, pretty thoroughly. So I took all the math, chemistry, and so forth.

Brother, George Francis Reed, a Mining Engineer

Swent: You knew you wanted to be a mining engineer?

Reed: Pretty well, yes. Because my older brother George was already a graduate mining engineer.

Swent: Where did he study?

Reed: Here at Berkeley [University of California]. He had gone to UCLA [University of California at Los Angeles], but they didn't have any engineering then--only pre-engineering, the first two years. They did have geology. He had gone through, and by kicking around and following him around, and also my dad taking me to visit him, why, I'd gotten pretty well indoctrinated in the idea.

Swent: Where was your brother working?

Reed: When he finished here in 1937, Dad had contacts, and he got a job at the Dome Mine in Timmins. He went up there and worked for I think maybe two years. Then he came down and worked at Ruth, Nevada, at the copper mine, and at the Cactus Queen, I think it was, somewhere around Mojave. In 1940 he was managing a little gold mine near Modena, Utah.

Swent: Had you visited some of these places?

Reed: Oh, yes. In fact, I went with my dad when I was about fourteen; it was the summer of 1937. Dad took me up to Canada. George had been up there several months by this time and was working way down in the Dome Mine. I'm amazed that my dad was able to take me the places he did. I wasn't able to take my own kids later, in Missouri in 1955-60, they had gotten so fussy about things by then. I remember we went to the 2,200 level in the Dome Mine, and I was very impressed by the stretch in the cable holding the cage. You know, when you go down that far the cable is like a rubber band, and when the cage comes to a stop it goes "boing" and bobs a foot

or so, like a yoyo. We tramped way back, somebody took us in, and there was my brother working at the face of a drift.

Swent: Did you have to wear protective gear when you went in?

Reed: I don't recall if they had hard hats at that time. They must have. I suspect probably they clomped one on us. I don't remember.

Swent: The insistence on a hard hat came in after the Second World War, I think.

Reed: Brother George gave me my first hard hat when I worked with him in August 1940, age seventeen. I went over that summer and worked with him near Modena, Utah, in a little gold mine he was running, the Etna Mine. It's west of Cedar City in southwestern Utah, very near the Nevada line. Two partners owned the mine, a Mr. Vanderbush in Los Angeles and Pietro Aria in New York. I gather that Mr. Aria was quite a famous concert musician in his time. Mr. Vanderbush hired George to run the mine a while, ship a little ore, and see if he could develop anything worthwhile.

I rode over with Mr. Vanderbush in the car on one of his inspection trips, and then I stayed with my brother for three or four weeks. I don't think he paid me anything, but it cost me nothing and was a good experience.

Swent: This was while you were still in high school?

Reed: Yes, I was seventeen. It was the summer of 1940, before I graduated from high school in February 1941. I ran the hoist for him, and I helped him. He gave me a title right off. He said I was the sanitary engineer. Everything was carbide lamps, and when the spent carbide comes out it's slaked lime. That goes in a bucket when you clean it out, and you fill the lamp with fresh carbide. He gave me a wooden powder box full of that slaked lime and a little fire shovel, and I was to go around to the outhouses and sprinkle that in. That's why I was the sanitary engineer. [laughter] I had a title, even.

I learned something about mining from George, and at that time he gave me a hard hat. I've got a story about that hard hat. I went to Chile four years later, and I had that hard hat with me. But the company issued hard hats, so I thought, "I'm not going to use my hard hat; I'll save that." So I took the company hat and wore it through the three months of what they call *practicante*, or breaking-in period. Finally I was a shift boss, and I was still wearing the company hat. A shift boss had perhaps six Chilean straw bosses who handled the 150-200 men involved, and this sub-boss was called a *capataz*, or *cabo*. My head *cabo* was Wenceslado

Amigo. He spoke just a little bit of English, maybe, if he had to, but he was a very accommodating and understanding guy--good for keeping a young gringo out of trouble. He later became a shift boss himself.

Cabo Amigo and I went into a drift one day--we were going our rounds together--and about every ten or fifteen sets there was no floor; it was open. That was where you dumped the cars. It was a grizzly, with a raise going down, and the rails went over it--eighteen-inch gauge railroad track that you pushed the cars on. There was a handrail on each side, and it was a four-foot square hole in the floor. Of course it went clear to the bowels of the earth; you didn't want to go in there. So when you came along to that thing, you put one foot on the rail and hung on and stepped across with one step. That's if you saw it! But for those who missed it, there were the two rails going across, and down below them about two feet there was a safety rail going crossways, so that if you missed the one you might land on the other to keep you from going down--something more to grab hold of.

We went on in, and there was a muck car parked. You squeezed by that one-ton car. It was parked right by the *buitra* (pronounced "*huitra*" in Spanish), which is what they called that dump, or grizzly. We went on in past that, carrying our lamps and so forth. You didn't put the lamp on your hat (there's another story about that), but we carried these big eight-hour, so called, hand lamps like this [demonstrates]. We saw the timber crew that was working in the face, and then we started out. I was ahead of *Cabo* Amigo, and I came to that car and was squeezing around it. My lamp was in the car, in my hand, and I forgot all about the *buitra* being right there. I took one step with the lamp still in the car, so I didn't see where I was going. I stepped right in the *buitra*. I hung up on the rail, and that was all right, but my hat went off and down the buitra. Of course, nobody ever recovered it; it probably got crunched up or something. I remember going into the boss the next day or so and saying I needed a new hat. He said, "What's that you're wearing?" Well, in the meantime I was wearing my own personal hat. So he said, "That's fine. You lost." [laughs] I kept that hat for a long time.

Swent: Did they actually lose people down those holes?

Reed: Oh, yes, rarely. The bad part was not just the fall down the raise, but in addition the raises were like the branches of a tree, with perhaps eight *buitras*, in several different drifts, all feeding into the same system. If you went down very far, maybe nobody would dump rock in where you fell in, but somebody else could be dumping rock in somewhere else that would come down on top of you before they got you out. So it was a bad business if you

ever went down there. But the rails were pretty effective at hanging you up. You'd hook an arm or a leg on the rail and be able to climb out, thoroughly shaken.

Swent: You'd be very careful after that.

Reed: Yes, you'd learn to always have the lamp out in front of you.

II PREPARING FOR A CAREER IN MINING

Outdoors in Out-of-the-way Places

Swent: So you wanted to be a mining engineer because you had seen your father and brother's work.

Reed: Yes, they had kind of indoctrinated me. And I like outdoor things. By visiting with them I saw that mines were usually in out-of-the-way places.

Swent: Yes, indeed!

Reed: I loved to hunt and fish; my dad had taught me to hunt and fish and camp and so forth since I was about five years old. When I was six, in 1929, we hiked into the sierras near Mammoth Lakes, and when I wore out, George, fifteen, ferried me out in a packsack. I didn't want a life in a city or in a factory or something else. I think it was just a kind of a natural thing. Indeed, when I was finishing here and starting to look for a job, I think one of the major considerations was where it was. So I picked the Coeur d'Alenes. I had one job lined up there because I knew about the wonderful natural conditions up there. I had learned to ski by this time, in high school. Then the next job I had lined up was in Happy Camp, California. You know where that is? It's half way between Redding and Eureka in those northern mountains. It's a very obscure place. It's still an out-of-the-way place. They were mining copper there during the war, and I had a job all lined up there.

It was nip and tuck whether you were going to get deferred in those days. I'd been through school, finally finished, and I wanted to get somewhere mining something that was needed.

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Reed: So at the last minute I decided it better be Chile or Peru.

Swent: This was when you were finishing college?

Reed: Yes, here [in Berkeley] in February 1944. That's why I ended up in Chile. But back to why I chose mining, even when I got through studying I wanted to be outdoors. Going back to high school, I took all the college preparatory courses, and as much shop as I could, because mechanical things were important, too.

Swent: Were you a good student?

Reed: Yes, I did well in school. That leads to another subject that I've got a story about. When I was graduating from Fairfax High School in Los Angeles, about January 1941 I got a call from the vice-principal's office. I don't know how he introduced it, but it turned out that if willing I could be interviewed for a possible scholarship at a very unique junior college which I had never heard of, called Deep Springs, California. I've learned a lot about it since.

Deep Springs Valley is in the White Mountains between the Owens Valley and Nevada. You know where Bishop is? The first town south of Bishop is Big Pine. There's also a Lone Pine farther south. There's a road from Big Pine that goes over to Nevada through Deep Springs Valley, and there's a school in there. This school was endowed and founded in 1915 or 1917 by a man who was in the steel business. It was a very exclusive boys' school; they only had about twenty boys there at a time. It was a working ranch, really designed, I think, for the sons of wealthy people who maybe became maladjusted, or their parents just wanted to give them a taste of reality. It was very tutorial, you know, but the boys themselves had assigned duties. They raised the cattle, they raised the crops, milked the cows; they ran the ranch, in addition to their studies. It had a very exclusive faculty.

I didn't know anything about this, but the principal said, "Do you want to be interviewed?" I said okay, I would find out about it. Apparently two students were selected in each high school in Los Angeles to be interviewed by this man. One Saturday I put on my coat and tie and went down to the Biltmore Hotel downtown. There were a bunch of boys sitting in a row outside this room, waiting their turn to be called in. This guy called my name, and I went in. He shut the door, and the first thing he asked me was, "John Reed"--he was looking at my file--"are you any relation to the famous John Reed, the Bolshevik?" Heck, I didn't even know what a Bolshevik was, much less who John Reed the Bolshevik was. So I said no; I professed ignorance. That was the end of that part of it, as far as he was concerned. He went on and interviewed me.

I don't remember, but I think I finally concluded that, really, it was time I started making tracks through college. This sounded like a lot of fun, but it was like liberal arts; it wasn't going to compare with two years of pre-engineering at UCLA. I may have come right out and told him that. I don't know, I might well have, and maybe that's why I never got any further contact from him. I always thought maybe he thought I was not very well educated if I didn't know John Reed, the Bolshevik.

I had all kinds of other interesting experiences later in my life, all related to that other John Reed, and aometimes I wondered if maybe that school was a beginning point for the Young Communist League or something--which it wasn't at all, as I found out more about it. The funny part was that as soon as I got home to my mother, I said, "Who's this John Reed, the Bolshevik?" She cracked up, because she knew all about that; it wasn't very long before I was born. Then there was a movie, "Reds," and a book, Ten Days that Shook the World, by John Reed, which is well known.

Swent: He's buried at the Kremlin, I think.

Reed: Yes, he's reputed to be the only American buried in the Kremlin wall. Anyhow, that all got explained to me by Mom, and then I went on. There have been many sequels to that business all through my life; that's what's funny about it. The last one was just a couple of weeks ago. I saw the obituary of a graduate of the Colorado School of Mines in Golden. He worked for Boeing, was a petroleum engineer, and he was from a very upper-crust academic family at Cornell. They had sent him to Deep Springs Valley school as a kid, and it was written up in his obituary. There was something to the effect that he had put it in his memoirs.

I contacted his widow in Seattle, and she very graciously loaned me her copy of his memoirs, which she helped him write. There were about fourteen pages about Deep Springs. It left a tremendous impression on him through his whole life. Now I have all the information about Deep Springs that I often wondered about, and I just got it two weeks ago. So it's been following me along all this time.

The sequel to some of this is that I never got around to reading Ten Days that Shook the World, but about 1965, at Golden, the state department contacted me. A visiting professor was coming over, a mining professor from Russia, and he wanted to spend a few days visiting us. Would I accept that? Sure. Of course, I had had very little contact with Russians up to this point; at a few meetings I'd meet never one, but always two or three. You wondered who was the technical person, and who was the KGB riding herd on him. They were always very non-talkative, and no smiles. So I

thought, "Lord, what am I going to do with a Russian? How long is he going to be here? A whole week? Ye gods, this is going to be awful." But I couldn't do anything about it.

They told me what flight he was arriving on, and I should go meet him. I went to the airport, and I stood there looking at all the people coming off the plane. I didn't see anybody who looked like a Russian, and nobody stepped up to me. Finally I went back to the desk, and either I called for him or he called for me. His name was Mikhail Agoshkov. Finally I met him, and he was a little twinkly-faced guy who reminded me of my dad. He was real friendly, and he spoke broken English but quite understandable. Do you know the mining engineers' handbook, Peele's Mining Engineers' Handbook, two thick volumes? He translated that into Russian for all Russia. So he at least knew how to read English, and, as I say, he was pretty good at speaking it.

He was great. He stayed in the local hotel in Golden, but he ate dinner lots of times at our house. We'd take him for a drive with the family, and he liked the kids and so on. We had a great time, after we got over the shock. When he was leaving, he said, "You must come and repay this visit in Russia." I said, "Oh, sure, sure; that would be nice," and I forgot about it.

About two years later, in 1967, Neville Cook, Director of the Mining Research Laboratory of the South African Chamber of Mines [and now Professor of Mining, University of California at Berkeley], had me all lined up to go to South Africa. They were going to pay me first-class, round-trip fare, and I don't know but what I even had the tickets already. All of a sudden I got a wire from Agoshkov in Russia. He wanted me to repay the visit and come as his guest at the Fifth International World Mining Congress in Moscow. All I had to do was pay my way there; they would take care of everything within the country.

Well, I managed to work it out. I talked to my travel agent and changed the one direct first-class ticket to Africa to tourist-class. I went to Sweden and visited the school of mines there, and then I went into Russia and spent all this time in Russia. I came out to England and visited Professor Edward L. J. Potts up at Durham University at Newcastle and then went on to South Africa. And I came home first-class, the travel all taken care of. But the point was that it was all at the last minute, and I had no time for preparation. In fact, I had to get my congressman to get my visa from Washington, because the Russian embassy wasn't answering. I got a little Russian pocket dictionary, and it didn't occur to me until I got over there that I couldn't read the script! It became a welcome gift to my young Russian translater and guide.

A Visit to Russia and Being Mistaken for John Reed the Bolshevik, 1967

Reed: When I got off the airplane in Moscow, Agoshkov was there to meet me. But he sent one of his people, somebody who had an entree into the immigration section, to greet me at the plane and speak a little English to me and lead me to the immigration desk, check the passport, and things like that. The immigration man took one look at my passport, and he said, "John Reed!" His eyebrows went up, and it struck me then what he was talking about. He was yammering in Russian to this Russian guy, and they wanted to know if I was any relation. I professed no. That went on all the time I was in Russia. That name, John Reed, in Russia is about like Benedict Arnold or Lafayette within, say, fifty years of our revolution, because it was fresh in their minds, and he was very well known. Everywhere I went they would say something about this.

I spent about a week in Moscow, and then they flew a bunch of us to different places. My group went to Krivoy Rog, which is an iron mine down in the Ukraine. We enjoyed that. When we got back, whereas I had been traveling with a group--the other delegates to this congress--they sent me up to Leningrad all by myself with my interpreter, a young fellow. That was more like a special trip, their sending me there. Leningrad, I think, is the cultural center of Russia. We were going to be about three days in a hotel, and one of the first things my interpreter said was, "There are some newspapermen here who want to interview you." I was just a little bit leery.

Swent: What year was this?

Reed: This was 1967. They were getting ready for their fiftieth anniversary from 1917, so all the big buildings had scaffolding around them. They were cleaning things up and getting everything ready for the October celebration. This was all fresh in everybody's mind, so maybe that had something to do, too, with the fact that they would perk up at the name John Reed. All along the line I was a little concerned. A lot of people were more concerned than I. When we first arrived in Moscow, they wondered if the rooms in the hotel were bugged and all that kind of thing. There's a hotel for foreigners, Hotel Ukraine, I think it's called. It's beautiful--looks like a castle--but it's out of town, kind of by itself; you can't hobnob with anybody.

Agoshkov had put me in a different hotel in town. I don't know whether he put me in town because the other hotel was full; I doubt it. I think he thought I would be happier in a small hotel

right in town. This was the Hotel Budapest. I was the only person in there who spoke English; nobody in that hotel spoke English, even the waiters down in the dining room. It's a good thing he assigned this young interpreter, Sergei Panenko, to me. He'd come with a car and pick me up in the morning. He took good care of me, but once in a while he'd drop me off and I'd have to get my own meal, and I usually got my own breakfast, so I had to develop a little vocabulary.

When we got into Leningrad, I began to relax. But when they started talking about these newspapermen, I didn't know quite what to think. Sergei takes me down and we meet this guy on the street. He's got a car, and he's got a photographer with him. The guy spoke English, but I don't think the photographer did. The first thing he did was hold up--all in Russian--the book Ten Days that Shook the World, by John Reed. He asked if I knew this book, and I said I was ashamed to say I hadn't read it, but yes, I knew the book. He said, "We thought it would be nice if we took you on a personally-conducted tour of all the places that that John Reed went to during those days of the beginning of the revolution."

Reed had a safe-conduct pass, which permitted him to visit back and forth between the loyalist people, who were in the Winter Palace, which is now the big museum, and the girls' school for the nobility, Smolny, where Lenin had set up his headquarters. They've got this school designated as a shrine to Lenin, so we went there. There is a lecture hall where the congress got together and did all their shouting and so forth. There's a huge picture of Lenin on the wall, and all the time my guide has me standing there, talking to me and showing me this room and telling me the history, that darned photographer bloke is kneeling down, taking pictures of me with that great big portrait of Lenin in the background. I was getting more and more nervous, wondering what they were going to use all this for. I enjoyed it, but I was apprehensive at the same time.

I never did find out. I always thought they would write an article in the paper, but I never heard about it. When I got home I told the state department right off what had happened. I said I didn't think I had said anything wrong, but I wanted them to know so that if they got something out of context they would know about it. I never heard boo about any of it. So all I can say is that they gave me a real nice tour, which I came to appreciate because they showed me everything. Another little thing, they took me to the big heavy cruiser, called the Aurora. It's a shrine now. That's where they got the navy to go along with the revolution before anybody else, and it was from that ship that they practically poked the big cannons in the window of the Winter

Palace and said, "Give up or else." And they did. Now it's tied up to a wharf there, and people go on it and tour it.

There's a little guard house and a gangplank over to the ship. At the guard house there are two soldiers with submachine guns. This guy drives me up there and gets out and talks to them. He says he wants to take me aboard, and they say, "Oh, it's closed; it's not open to the public now."

He comes back to tell me, and I say, "Okay, okay, let's go; I don't care."

But he says, "No, no, wait a minute. I'm going to go talk to the officer of the deck and see if I can't get permission under the circumstances."

I said, "Well, if you have to." I was very apprehensive about those characters with the guns. But darned if he didn't get permission. There was an old gentleman--I think he was probably a retired chief petty officer--in a straggly white uniform. You know, all Russian uniforms look pretty--one size only. Finally he got permission, so he took me over there on a personally-conducted tour, all by myself, and the old officer was so solicitous. He showed me the radio shack and this ancient wireless equipment. That's where the message went out to the whole country that the revolution had in fact come to pass. When I got over my nervousness, I was very happy about it. And they took me to all these other places.

You see my malachite tie pin? Have you ever been to the Winter Palace and seen a room they call the malachite room?

Swent: I've seen the pillars at one of the churches, the St. Peter and Paul Church, I think, all made of malachite. It was gorgeous.

Reed: Right; you can't believe it, can you, when you see it? There's a beautiful big hall in that museum which was all closed up for being rejuvenated and not open to the public. But, again, these people knew my interest in geology and mining, and they went to the director of the museum and got permission to take me into that room. I was able to take some colored slides. There are two entrances, with a little flight of steps, with a column on each side about twelve inches in diameter and two stories high. There's a great big urn or vase of malachite about as high as a man, and all the facing and mantelpiece of the fireplace is malachite. The rest of the room is stark white, so it really shows up. I was fascinated. And I got to see this because of my namesake, John Reed, the Bolshevik!

Swent: It was amazing that they would do this in 1967, because Americans weren't all that welcome then.

Reed: No, that was in the middle of the Viet Nam war. But this was part of this cultural exchange. One professor had been one place, so the other professor got to return the visit. I really enjoyed it. And this John Reed the Bolshevik thing has been with me all through my life. Next time I go to Owens Valley--I'm going to drive over there now--I'm going to visit the Deep Springs School. I'm just curious.

Swent: This was a junior college, you said?

Reed: In effect. It would have been like the first year in college. I think in the beginning it was like the last year of high school and first year of college, but then way back things changed. By the time I was talking to them, I'm pretty sure it was like the first two years of college. If that had been all liberal arts, it might have been a wonderful experience for me, but it wouldn't have gotten me ahead in mining at all. It might have met just one or two requirements, like poli sci [political science] or something. It would have just added two years to my sequence, and I never would have gotten through; that's what it amounted to. So it's a good thing I didn't do it, but it's intrigued me all this way from a long time back. It's funny how it keeps popping to the surface.

Swent: You went to UCLA instead?

Reed: Yes. I started in at UCLA and was able to live at home, which was very inexpensive. I traveled back and forth on the bus. Then the war started.

Swent: What change did the war and Pearl Harbor make in your life?

Reed: In the first place, the first summer I was in college was the summer of 1941. Well, we weren't in the war yet, so there was no summer school. I tried to get a job; my dad knew some diamond-drilling people in Los Angeles, old friends of his from up north. But all their jobs were underground, and the laws wouldn't let me work underground when I was seventeen. So I couldn't do that.

My older brother Jim was working on a huge yacht, the Vida, that belonged to Earl P. Halliburton of oilwell cementing fame. It was 236 feet long--about like a destroyer. It had been built in 1929 for J. P. Morgan and cost fifteen million dollars or so. Halliburton had gotten hold of it for a song, basically, and he was running it like a school ship. He had a licensed captain and a couple of mates and a chief engineer, but the rest of the crew were young boys, high school boys and so forth, who were studying under

the guidance of the older people. My older brother Jim had been on it for a year or two and was like a bosun's mate. In other words, he was senior to the high school boys like me. I spent the summer on that boat and learned to handle lifeboats and launches and things like that. We were in Port Hueneme Harbor near Oxnard. It was a new dredged harbor, and later it became a Seabee [Construction Battalion] base and I don't know what all during the war. That was an interesting experience. It didn't make me a lot of money, but I learned quite a bit. Then I went on at UCLA.

When Pearl Harbor came, the whole university immediately started going towards three semesters continuous schooling. By the summer of 1942 I took mineralogy, other geology courses, surveying, and everything else right through the summer. By October of 1942 I had finished the equivalent of my first two years at UCLA. Then I came up here [to Berkeley].

University of California College of Mining, 1942-1944

Swent: What attracted you to come up here?

Reed: For mining. Down there it was just basic engineering and geology.

Swent: You didn't consider going someplace like Colorado or Arizona?

Reed: No, I was looking for an in-state mining school, and my brother had been up here. I was geared for Berkeley all the time, but I had finished what I could do at UCLA, and it was time to come up here. It turned out that the last two years of college went from October of 1942 until February of 1944--all of 1943, plus one semester; four semesters is what it was, but it only took a year and four months because it was so continuous.

Of course, this is where I met Dr. [Donald] McLaughlin, Professor [Walter Scott] Weeks, and Bernard York. I did well here.

Swent: Did you have any choice of curriculum, or was it pretty well set?

Reed: In mining it was pretty set. I took some extra things. I took extra courses from Carlton Hulin--two courses that I recall, secondary enrichment and structural control of ore deposits.

Swent: That was geology?

Reed: Yes. I carried a heavy load, twenty hours the last couple of semesters. But I did very well, and I loved it. When I finally

got out of the pre-engineering and into the real mining and geology, I couldn't get enough of it then.

Swent: Did you do field work as well?

Reed: Oh, yes, we did the geology of all the Berkeley Hills on Saturdays; this was for field geology. Come Easter vacation, we spent a week around Copperopolis and Angels Camp in the Mother Lode country with Dr. [Nicholas] Taliaferro. We had a lot of indoctrination up there and a lot of first hand experiences with rattlesnakes. I had run across rattlesnakes before, but, boy, that trip was something else. We got so jumpy with rattlesnakes that we couldn't hardly walk anymore, we were so afraid. Nobody actually stepped on one, but we came within an ace of it two or three times and just scared the dickens out of us.

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Swent: So you didn't take any chances with rattlesnakes?

Reed: Oh, boy. We were up there with Olaf Jenkins, the state geologist. He was buddy-buddy with Taliaferro, so the two of them were with us all the time. He was just along sort of as an adjunct. I remember one time Olaf Jenkins and I were walking down a hill together on a gentle slope in some natural dry grass, and we were busy talking about some deep geologic subject. My eye just happened to fall down on the ground where his next step was going to go, and there was a rattlesnake. It was trying to get away from us, but his next step was going to be right on its tail. I grabbed him, and we stopped. Then we started looking for stones. I don't think we ever got the rattlesnake; he got into a clump of bushes. That was one experience.

In another place, my partner and I were crawling along a real steep slope of the Stanislaus River, right around the corner from Copperopolis. It's all metamorphics, and all the rocks are standing up on edge like ribs on a steep bank. We were picking our way around, trying to get from where we had been to where we had to go. We were actually hanging on with our hands, and about fifteen feet below was the river. If we didn't get across at this place, we had to go way around, so we were trying to get across. These ribs would stick out and leave a little "v." You were looking for a place for a foot and a handhold. I was leading, and I was looking for a place to put my foot on the next step. I saw this little pocket back in the "v," and I was just about to put my foot there, and here was a snake all coiled up, asleep with his head on his coil, looking out from that very place where I was going to put my foot. Of course, I reared back and stuck the foot across to another out-rib. There I was, spread-eagled, with a hand on each

side, a foot on each side, and the snake looking at me about three feet straight in front of me--and water underneath me. I was just sweating, and I let out a yelp. My buddy was standing nearby, but he couldn't see why I was so scared. When I told him, then he got scared. About this time the snake woke up, lifted his head, and began to rattle. I was afraid to move. I was perfectly safe where I was, but where was I going to put the foot the next time? Would there be a partner?

It was things like that which got to us so badly. During the next day or two when he and I would walk through the brush, one of us would move and the other one look. We weren't getting much geology done, I'm afraid; we were too worried about snakes. But it was an interesting trip anyhow.

Swent: Because of school being year-round, you didn't have any summer jobs, then.

Reed: No. That was the Easter vacation of 1943, and at the end of that summer there was a little break of about three weeks between the summer session and the fall semester--my last semester. So for that three weeks, strangely enough, I got a job at Copperopolis. They were running an old copper mine there. During the war, you know, they mined whatever they needed wherever they could get it, whether it was economical or not. There were subsidies and all kinds of things--but not for gold. That was the situation. There was a copper mine there, and another one up at Happy Camp. It was the same kind of a thing, not a big deposit, but it was copper that could be had.

I lived in the hotel in Angels Camp and worked night shift at Copperopolis for that three weeks. That's the only technical "summer employment" that I had, because I didn't have any spare summers. That was enjoyable, too.

Swent: Where did you live in Berkeley?

Reed: In a boarding house that is no longer there. It was at the head of Channing Way, straight up two blocks above the circle on Piedmont. I think it's Waring Street that Channing dead-ends into--the street that goes into the end of the stadium. I know when the crowds came to the football games, we'd be leaning out the window watching them all walk by outside. That boarding house was as handy and as cheap as any at that time. I think it's some kind of a fourplex now.

Swent: Did you make friends that you've stayed in touch with?

Reed: Through the years, yes. In fact, this next May, Phil Dettmer and I are going to make an expedition to Alaska. He's a metallurgist,

and he's been all over the world. He's been in the iron beneficiation business, in smelting and pellet-forming, and things like that. He'd be a good candidate for you to talk with. He's very observant.

Swent: You were classmates?

Reed: Well, he was in metallurgy, so I don't think we were really classmates. But I guess we were both in Theta Tau and the Mining Association and so forth; it was a close-knit group whether you were in mining or metallurgy.

Swent: Was it a big class?

Reed: Not by the time we graduated, because most of the people had either been drafted or enlisted or something else. Actually, we were the last four mining students who graduated in mining--Bill MacDonald and I, Ed Thurbin, and I think the other guy was Steve Shutt. I don't know whatever became of him. Strangely enough, Thurbin also came to Braden, so there were three of us, out of the four, who went there.

Swent: Mining became less popular for a long time, didn't it?

Phil Dettmer

Reed: Yes. Dettmer had the most fascinating experience. He went into the military, in the Army. He was a graduate metallurgist, and the best thing they could find for him was to be in a company of heavy equipment maintenance--trucks, tractors, and things like that. He ended up, just at the end of the war, on Okinawa. They were preparing to go into Japan next, when they dropped the [atomic] bomb. Fortunately that stopped the fighting. He was sitting there fixing trucks and so forth, and he saw in the GI paper that [General Douglas] MacArthur, who was in Japan by this time and trying to get the Japanese economy and industry back on its feet and going, needed technical people for his staff. One of the things he needed was a graduate metallurgist, so Phil saw this and said, "Hey, that's for me." He took it to his commanding officer and said, "I'd like to put in for this."

The commanding officer said, "No way. I need you here to fix my trucks." He wouldn't pass it.

Phil had been saving cigarettes as barter, and he went to the air transport people [MATS]. By putting a few packs or cartons of

cigarettes out, he got a seat on a plane going to Japan over a weekend. He got a weekend pass, and he flew into Japan. He went into the personnel office where they were looking for these people and told them his credentials and qualifications. The guy said, "Fine, but how did you get here?"

Phil said, "I asked my commanding officer, and he wouldn't put me up for it, so I thought I'd better come and talk to you myself."

The guy said, "You just go home, and we'll take care of it."

Phil bartered his way back home again, and in a week or so his commanding officer got a letter requesting his presence. So he spent about three years in Japan, with his wife, yet; his wife got to come over. They traveled all over Japan in those first years after the liberation, putting things to rights; steel mills and so forth were all in tatters or nobody was around or whatever. He got to know all these people and saw most interesting things. There are some wonderful stories he can tell. Then he came back here and went on with the rest of his life.

One of the really weird experiences was after they got back here. They lived in the Bay Area, and had a good friend who had married a Japanese girl. There was a lot of ill feeling about Japanese in those times, but the Dettmers had been living there and been well treated, so they were sort of sympathetic. This couple would have visitors from Japan and would like to have a dinner party for their visitors with some congenial Americans, and such were hard to come by. They would ask the Dettmers, and more than once they went to the dinner parties. They'd meet some Japanese people who probably spoke minimal English, and who would remember names under those conditions?

They met two men at one of these dinner parties and asked them what they were doing in this country. They said they were in the automobile business in Japan. "We think we ought to develop our industry, so we're over here on a study tour to see what's done in this country." The Dettmers' impression of the Japanese motor industry at the time they were there was--when you went for a taxicab, it was a little jitney with a big thing like a teakettle on the back end that generated methane from charcoal, and that's what ran the engine. Your seatmate inside was likely to be a gunny sack full of charcoal briquettes to put in that kettle. A real rinky-dink sort of a thing. They almost choked, trying to keep a straight face, when these guys said they wanted to put up an automobile industry in Japan.

This was about forty years ago, and just a few years ago the Dettmers recontacted this couple and found out that one of those

men's name was Toyota. Those Japanese did their homework very well! These are the funny kinds of things that come to pass.

Swent: Is there anything more you'd like to say about your university experience? Were there any other teachers who were particularly influential or helpful?

Reed: Taliaferro and Hulin.

Swent: Did they involve themselves in helping you get a job?

Reed: No. I don't know how I came by the job in Copperopolis; maybe through Bernard York, or perhaps by a contact made during the geology field trip that spring.

Swent: You were not subject to being drafted as long as you were in school?

Reed: That's right. I had a 2-A deferment; as long as you got good grades and went full time, you were deferred for six months at a time. And if you were studying what they considered an essential industry--preparation to do something necessary. The supposition was that if you finished and went promptly to work in an essential industry, you would continue to be deferred. That was the basis for my going to the biggest copper mine I could find, thinking that that would do it. As it turned out, some people still got drafted, even from down there. But I figured that was the best bet, to go down there to Braden.

Swent: You said that you applied to Cerro de Pasco at the same time?

Reed: Yes, but the letters to Peru had to go back and forth, and it just took longer. I had already accepted the Braden job when the acceptance came from Cerro, so I had to say, "Thanks, but no thanks."

III ENGINEER, BRADEN COPPER COMPANY, CHILE, 1944-1950

Getting to Chile in 1944

Swent: Where did you interview for the Braden job?

Reed: It was all done by mail from the New York office. They were so anxious to get anybody that if your application looked acceptable, I guess they just processed it. And they didn't even confer with the people in Chile; they didn't take that time. I graduated in February and went down to Los Angeles and started getting ready to go. Bill MacDonald joined me down there, and we left for Chile on the 17th of March, St. Patrick's Day, 1944.

Swent: How did you go?

Reed: On a DC-3 from Los Angeles. We left about eleven o'clock at night. The first flight was supposed to go to Mexico City. You put down somewhere like Calexico to go through immigration, and then I think we went down to Mazatlan to refuel. Then we were supposed to go over the mountains to Mexico City, and that was the worst time I've ever had in an airplane. There was a hellacious thunderstorm. I hadn't had that much experience flying anyhow, but it seemed like the end of the world--the lightning, the thunder, the rain, and the plane just doing nip-ups. I was deathly sick. Finally it got so bad that we never got to Mexico City; we sat down at an auxiliary emergency field that was about eighty miles outside of Mexico City, and they took us in on a bus. So it really was bad; it wasn't just me.

I don't know if this had anything to do with it, but this was wartime and you had priorities on those planes, and a DC-3 doesn't carry that many people--twenty-odd. We had an extra day in Mexico City because of this bus ride, and then we were supposed to get on another plane and go to Panama. We started off to Panama, and

again you were supposed to make that in one jump. We landed in Tegucigalpa, and it was getting on towards dark. We weren't going to make it to Panama in daylight, and at night it was under blackout, so we set down at San Jose, Costa Rica, for the night. That was unscheduled. Then the next day we got to Panama. We got off-loaded or bumped or something, so we spent an extra day in Panama. Never did get to see the canal; I never have seen the canal in all this time. We just stayed at our hotel there.

When we finally left there we were supposed to go to Lima, I think, for the next jump, but we went to Quito, Ecuador, and waited out a storm there until we could get up out of the canyon. We finally got as far as a little town in the north of Peru, Trujillo, and spent a night there that wasn't scheduled. Then we got to Lima and had a contact there, because one of our classmates was Manuel Llosa. He gave us a letter he had written to his parents. His father was a *diputado*, in the congress, so they were upper-crust Peruvians. They took us to the country club and all around. There was a layover, so they had us two nights there, and that was nice. They introduced us to a little shot of straight pisco, the national drink, and thought Mac would always appear a "gringo," with his blond hair and blue eyes; but with my dark hair and eyes, I'd soon be a "roto Chileno."

I guess from there we got to Santiago. But instead of being four days, we were eight days. I think the company had given us up for lost. We got to Santiago over a weekend, and being very conscientious we tried our best to contact the company, but we couldn't do anything over the telephone with our Spanish at that stage. So we just sat in Santiago for a while, and finally we got in touch on Monday.

Swent: Then you went out to the mine?

Reed: Yes, I guess we went to the company office and went out by train, which was how you had to get there at that time; the roads in Chile weren't much good. I notice in my letters here that most of them were gravel. The railroad was the main transport.

Swent: Braden belonged to Kennecott?

Reed: It was a wholly-owned subsidiary.

Swent: Were there Chileans on the staff?

Reed: Most of the shift bosses were supposed to be Americans. There were *capataces*, sub to the shift bosses, but when they didn't have a gringo to put in as shift boss, then they'd put in a Chilean.

Swent: But the top level was all American?

Reed: Yes, almost, but that wasn't such a whole lot of men in that big mine. There were three shift bosses on each section level for the three shifts, but there were only three operating sections in the mine. That would have been nine shift bosses. Then there would be a level foreman on each one of those, and a mine foreman, and two or three assistant mine foremen. Thirty or thirty-five gringos were the total staff in the mine.

Swent: Were they all Americans, or did this include other nationalities as well?

Reed: Mostly Americans. There were Canadians and a few English--not in the mine proper, but in the engineering section. They had one Finn, named Kauto, but mostly it was Americans and a few Canadians.

"*Practicante*," Apprenticeship Period at El Teniente Mine

Reed: I've heard people really come down hard on this particular phase of the Braden system, but I thought it was very effective. When you first got there, naturally the first thing you really had to do to be useful was to learn Spanish, if you were going to be a supervisor. And you also had to learn the ropes. So they had what they called a *practicante* period, apprenticeship, if you will, which lasted three months. The main thing was heavy timbering, because it was a caving mine where the whole idea was controlled collapse of the workings. You just kept them open enough to get the rock out, and the whole thing was caving in from the top of the mountain down. So good timbering practice was essential.

As a *practicante*, you spent the first six weeks as a timberman's helper. Your *maestro* was a good, cracker-jack timberman and also a tolerant type who would not bedevil you too much, and would teach you what you needed to know and be a little bit tolerant of a stupid young gringo. You were introduced to him, and he spoke no English. You were going to be his helper (*gancho*), that's all; you did what he told you to. You carried his tools. You went to the *bodega* (tool room), and his tools were all wrapped up; a crowbar, a saw, a hammer, a chisel, and a few other things were all wrapped up in a bundle in a gunny sack, checked with a brass tag. When you met him in the morning he handed you the brass tag, and you went to the tool room and got his tools, put them on your shoulder, and followed him out into the level. In the meantime, he'd gotten his assignment from the head timber *cabo*, and then you were with him for eight hours. At noontime you had your

bag lunch. You went in and sat not with the gringo foreman in the underground office, but in with the *capataces*. So all you heard was mining Spanish for eight hours. That was more of your Spanish indoctrination.

Then you went back out in the afternoon with him. He taught you the names of the tools--the shovel, the saw, the axe--and told you or showed you how to use them if you didn't know how. You did the heavy work, and he did the thinking work. And you learned.

The timbering--everything in that mine was extremely systematic and put down in a book; everything was done by the book. In fact, we called it the Braden Bible, and it was about an inch thick, mimeographed. Every last thing. The timbermen were paid on a piecework basis. Every stick of timber had its own price for being taken out and put in--chopped out, if it had to come out in pieces. That was the *cabo*'s job, to supervise all this. At the end of the shift, the timber *cabo* came around, and he had a sheet. He checked with the timberman, and the timberman told him, out of his head, everything he'd done that day. The *cabo* was looking around, "Yes, yes." He had a piece of *tiza* (chalk), and he would mark on these pieces of timber that he was paying for. He'd mark down how many of this stick of timber and a price, and how many of that, and so forth. The *maestro* was guaranteed a base pay (*sueldo*), but then there was piecework. Anything over the base pay he got according to what he had done.

Swent: If he put in more timber, he got more pay?

Reed: That's right. It was an incentive system. In fact, most of the work down there was paid on some kind of a contract incentive basis. The carmen (*carreros*) got paid by the number of cars they pulled out of the chute (*buzón*) and dumped in the *buitra*, the ore pass. The guys who drilled the boulders in the chutes and blasted them got paid by the *tiros* they drilled and blasted. They were called *buzoneros*, chute blasters.

There was one *buzonero* for every two carmen. If you can believe it, 30,000 tons a day was being pulled out by about three hundred carmen on three shifts into a one-ton car and pushed over by hand and dumped--30,000 tons a day being manhandled, one ton at a time. It was incredible, but that was the way it was done. Of course, the price of getting the rock out of the chute and into the car depended upon how hard it was to pull. When the rock was blocky, the pay per car loaded and dumped would be such that perhaps twenty cars would pay *sueldo*, and any more would be a bonus. Easy-loading chutes paid much less, requiring 100-150 cars to earn *sueldo*. The cars had a built-in weighing system such that the car was dumped, thus giving a total count at shift's end.

[Interview 2: March 22, 1991]##

Swent: Yesterday you were talking about the *practicante* period, and you were working as a timberman's helper. When you first introduced this, you said that a lot of people came down hard on this system, but I gather that you thought it was a pretty good system.

Reed: Yes, I thought it was a very effective one, because there's no question about it: submerging you in Spanish 100 percent, sink or swim type of thing--you have no out; you don't have anybody that you can go switch to English with. As far as the working part of it, you were doing hand work. Here you were a graduate engineer, but you were working from the bottom up. That didn't appall me at all; I thought that if you were going to be bossing these men, you'd better darn well know exactly what they were doing, how to do it, and how much work it was. Later the men would know that you knew these things and would respect you a lot more.

It did give you a little psychological thing, that you had worked with these guys as their helper for three months, and suddenly you were the shift boss. But I never saw that bother anybody, really. Certainly, the learning Spanish part of it was very essential and very effective.

That's why I get disgusted in this country now when we hear talk about bilingual education and two parallel routes, and all this hand feeding of immigrants who come in here. It was never that way fifty years ago, and it doesn't have to be that way now. I think it's a disservice to them; it only delays getting them weaned off of their own language and into a working knowledge of English. Now, I'm not against their retaining their native language. I think we need to do that, and it's a shame that fifty and a hundred years ago they went out of their way never to speak their native language, and they lost it all. Their kids had an opportunity to be bilingual, and they didn't get it; their parents didn't retain their native language.

To get back to Braden, I had heard people complain, not so much on the language part of it but on the fact that they had to demean themselves, if you will, to work as a helper and do everything from the ground up. But it was only three months, and you really learned the system that way. As I said, timbering was critical to that particular mine and that job. Ninety percent of your problem as a shift boss was keeping the timbering going, because if you didn't keep the timber up, the draw fell off and you couldn't get the ore out. This was a little drift, five by seven, with a one-ton car in it, and when the timber came in too far, you couldn't get the car through any more. Then the drift was shut

down until they lifted the timber and got the car through again. Well, all the time the draw is shut down in a caving system, the rock on top, which is just a great big gravel bed, is compacting and putting more pressure on the timber. So the way to save the timber is to keep the draw going to relieve the pressure. It's like a catch-22; if the timber goes down, you can't keep the draw up, so the pressure gets worse and the timber goes to pot faster.

So the *practicante* period, I think, was very educational and necessary. Most of the people who complain about the system have been to Braden but never stuck it out--never went through a three-year contract, never saw the end. They got fed up and left early on.

Swent: It was a standard three-year contract?

Reed: Right. Maybe I should explain that a little bit. I only knew one or two senior people who were brought down there. The usual young junior engineer with little or no experience signed a contract for three years on a single status. So if you had a wife, she wasn't going with you. Most of the fellows, fresh out of school, didn't have a wife in those days; there were very few who married in school.

So first you were on single status. Then it cost--I've got some of the early papers here--about $800 for the company to fly you down there. Salary was $200 a month to start with, and they held back $40 a month [see illustration]. That was being saved for you, in effect. But if you left before eighteen months, you didn't get that back; that was to repay the company for getting you down there. If you stayed eighteen months, you got that all back as credit at the end of eighteen months. The people who were really upset with the place or the system or whatever tended to stay the eighteen months, if they liked it or not, to get that retention back to pay their way home. Otherwise they had to get home on their own some way. At least this would pay their return trip ticket. So that was one thing that kept people there eighteen months.

I kept track during the six years I was there--three years in the mine and more or less three years out of the mine--and I knew personally a hundred young engineers in the mine alone--I'm not talking about the rest of the company--who had gone there, just like I did, and not stayed beyond the eighteen months. Some of them had stayed only a month or two, and most had stayed the eighteen months, just to get their retention money back, but never completed the three-year contract. That's a lot of turnover. I figured roughly just in my head that a guy is no good to them until he's been there about a year; he can't speak the language, he can't

BRADEN COPPER COMPANY
120 BROADWAY, NEW YORK
(No. 5)

PERSONNEL DEPARTMENT

December 29, 1943

r. John J. Reed
908 Channing Way
Berkeley 4, California

Dear Sir:

This will acknowledge receipt of your letter of December 23rd making application for a position in our organization. Will you please furnish us with your complete record on the application form enclosed herewith and return to me as early as possible together with photographs specified for consideration. The openings which we have for Junior Shift Bosses (Junior Mining Engineers) are for work at our underground mine operations at our property in Chile, South America.

We make a three year contract with transportation both ways and salary while traveling paid by the Company. The starting salary is $200.00 per month. In addition, we are paying a 10% war bonus. The starting salary, however, does not apply for the full term of the contract. Advancement in position and increases in salary come under the jurisdiction of the General Manager at the property, and depend upon the ability of the employee. Regardless of experience, our employees start as Junior Shift Bosses and work their way up. For the young man who has ability and works hard, there is chance for rapid advancement.

Based on the latest advice from the Plant, board averages between 800 and 1,000 pesos per month, which, at the latest exchange of approximately 19.35 Chilean pesos to the United States dollar, would approximate $41.50 to $51.00 per month. Single man maintains himself; room rent $4.00 to $6.00 per month.

Under present Chilean laws the Company is required to withhold monthly, 5% of each employee's salary for deposit in a Retirement Fund, along with an equal 5% contributed by the Company, which total sum is deposited with the Chilean Government in United States currency and converted by it into Chilean pesos at the rate of exchange then prevailing. These monies are deposited with the Chilean Government for the employee's account. The cumulative principal and interest on the aforementioned contributions are not payable to the employee by the Chilean Government until one year has elapsed after employee permanently leaves Chile. The refund is made by the Chilean Government in Chilean pesos. Due to the wide exchange fluctuation, it is impossible for us to definitely state what an employee's Retirement Fund will represent in United States currency at the time same is withdrawn.

Each employee is required by Chilean law to contribute 1% of his monthly salary to an unemployment fund and 2% for family allowance. The employer is required to deduct and pay these amounts to the Private Employee's Welfare Institution - a Government agency.

Under the Chilean law, there are also normal tax and surtax on income which the employee must pay. At the present time, on a salary of $200.00 per month (plus bonus), these taxes amount to about $12.50. The income surtax is on a graduated basis and is

applicable to net incomes in excess of 20,000 pesos. In other words, taxation, unemployment, family allowance, and retirement fund deductions under present Chilean law, on a salary of $200.00 per month (plus bonus), would amount to approximately $30.25 per month.

Because of a recent amendment to the Internal Revenue Code, United States citizens must pay U.S. income tax on income earned in foreign countries, unless they are resident in such foreign country for the entire taxable year. However, it is understood that Chilean income taxes paid for the corresponding year may be credited against the U.S. tax.

It is necessary that all our employees pass a physical examination for 9,000 feet altitude.

Booklet covering living conditions at the property and sample copy of our uniform contract are enclosed herewith for your information.

Yours very truly,

H. Otterstrom

mlc

Enc: Application blank
Sample contract
Booklet

Via Airmail - Special Delivery

STATEMENT OF ACCOUNT

FOLIO 128

...N COPPER COMPANY
CHILE

Rec. J. L.
Mina

RANCAGUA SEP 30 1945

...ER	ITEMS	MONEDA CORRIENTE		RATE	UNITED STATES CURRENCY DEBIT		CREDIT	
	BALANCE						510	65
1	Remittance				175	-		
1	Retention				40	-		
14	M. L. Cico	465	-	19.33	25	=		
20	J. M. Bruno				100	-		
21	Retention refunded				—	—	39	35
30	Cash Credit	1,546	70	1	—	=	80	=
	SALARY HOSPITAL				2	-	300	-
	RENT				6	-		
	CHILEAN INCOME TAX				7	85		
	FONDO DE RETIRO				15	=		
	1% FONDO ESP. CESANTIA E.E PP.				3	=		
	2% ASIGNACION FAMILIAR				6	-		
30	Voluntary income tax				1	05	30	=
					1270	02		
					1659	92	1659	92
							1270	02

do much of value. So in round numbers, say it cost the company $5,000 for a man to come down there, fiddle around for eighteen months, and go home--times a hundred is half a million bucks they've wasted, not to mention that it's not good in the organization, for morale, and so on.

Morale in the Mine Department

Reed: I had a big grudge against the way they operated things in the mine--just within the mine--in this hierarchy of thirty or thirty-five gringos. Some gringo had developed a philosophy in the mine, long before my time, based on chewing out your subordinate, just in your normal treatment of him--I mean, instead of just being more or less of a gentleman and maybe chewing him out if he did something wrong, to routinely treat him like the scum of the earth. In fact, it got so drastic--I mean, I was disgusted with it. It was applied especially to the new shift bosses, as if to humble and discourage them.

The first year I was there I was under the same mine foreman, and every morning or every afternoon, on whatever shift I came in, I would see him. If it was a day shift, I would see him all day. If it was an afternoon shift, I would be coming in in the afternoon to get my instructions from him for the night shift just before he went out. If I was on graveyard, I'd see him as I came out, just after he came in, and he'd have some more to say to me. He never had a decent word to say, and he always had the most ridiculous, long list of things that he'd want me to see to it were done, "Absolutely--*sin falta*--without fail!"

We all carried a little notebook, and you'd go in the office and stand there with your notebook and pencil at the ready and listen to this tirade. I have a relatively thick skin, and if somebody like that's talking to me, I just listen, saying to myself all the time, "What a nut you are," and so forth. But I'm writing down what he says, and at the same time I'm looking at this long list and saying, "There's no way I'm going to get all these things done. I'm going to have to assign the proper priority to them myself and not worry about it." So it was counterproductive, and it made a jackass out of him, as far as I was concerned.

As I went along, I made up my mind that if and when I ever got promoted a little bit, the next time a new fellow came in and was under my jurisdiction, I was going to treat him like a white man and try to help him understand the system and so forth. You know, there came a time when I was on a level by myself and was doing a

foreman's job, but I hadn't gotten the title yet. Because of the fellows who died in the mine fire, we were short-handed, and I was left to run a level alone.

A new man was assigned to my level for his *practicante* period. He had graduated in mining in 1941 and had been a combat engineer in Germany. He was perhaps four years older than I and a good man. I was alone on the level, so I was inviting him in to my office to have lunch with me instead of sitting over there with the *capataces* in their office. And didn't the next man up the line (my boss) making his rounds come by and find him in there with me, the two of us having lunch. I was telling him about the draw system and all the things that nobody ever explained to the new men, so I thought I was doing him a favor by teaching him these things.

When he left to rejoin his *maestro*, I got chewed out: "You know that's not the way to do it. They've got to eat over there with the *cabos*." You had to chew them out, you know. So it was even bedeviled onto the next one. It was the policy, and I still think it was highly counterproductive--again, going back to the hundred men who got fed up with it and left.

Swent: Do you think the other companies in South America operated the same way?

Reed: No, I don't. In fact, the rest of the Braden company didn't. Once I got out of the mine, it was like a different company. People didn't do that anywhere else in the company. It was only in the mine, where, incidentally, the roughest conditions were, as far as that's concerned. But there's no bloody reason for that, really. I think it cost the company a lot of money and a lot of good men, and it left a bad taste in a lot of people's mouths.

Now, to get back to the *practicante* period, I know a man who is now retired up in Seattle who is a very able engineer. He went down there with a standard contract, but he was married and took his wife with him. That really tweaked their nose, you see. They put us in a single men's staff house; that was all organized. I don't know what he did. I don't think they would even let him have her up in Sewell, give him a house or anything, which I can understand, really; it would have set a very bad precedent. I think she had to live down the hill on off-company grounds in Rancagua, which is about a four-hour ride on the auto car. He probably could only see her on weekends.

But the very idea that he had done that made them peeved with him, I'm sure. He worked with them for less than three years, very possibly until he got his retainer back. Then he had enough money to get on a ship with his wife and get home.

He has talked to me derogatorily about the *practicante* period. Well, maybe he was a little older and took it more to heart, that he thought he had progressed beyond the muck stick stage.

Swent: But it was only for three months?

Reed: That's right. I just thought that it was perfectly logical. I started with my brother with a muck stick in my hand, you know, and learned everything from the ground up. And it was so important with the language.

Swent: And did most of the men really learn Spanish?

Reed: Oh, yes. Well, within three months they turned around and said, "Now you're shift boss, and here are six or seven *capataces* to work under you." They only speak Spanish, and beyond them there are two hundred men you're responsible for. In the middle of the night, maybe you're the only gringo in the mine, or at least on your level you are, so you better be able to communicate. Oh, I don't mean our Spanish was fluent. The first thing you learn is to say what you want to do; understanding what they're saying back is the hard part. But at least you were capable of that.

Within a year I felt fairly comfortable in Spanish; I don't remember being particularly uneasy. I took my first two-week vacation south in Chile by myself. Oh, I'd run across a very few other Chilean tourists who spoke some English, and they would help me with my Spanish. I can remember one lady straightening me out on the reflexive forms. There were some dogs around this little hotel, and I was trying to say, "I like dogs, and the dogs like me." I was getting it all fouled up, because in Spanish you don't "like" something; instead, something pleases you. So those refinements I was still learning. But the fact was that in a year's time I felt able to get on the train by myself and go south to go fishing and sightseeing, and order my meals and so forth. I'm sure my Spanish wasn't very good at that time, but it served.

Swent: It would help employee relations, certainly.

Reed: Right. I knew how to get along.

To get back to the *practicante* period, you spent six weeks with the timberman, and then you spent maybe a week with a miner drilling a round, blasting it, and so forth. Of course, in those days it was all hand mucking, so you didn't have to learn to run a mucking machine.

I did later on, when one came in. I had to learn how to run the darned thing before I could turn it over to the Chileans, because they'd never seen one. I had seen one, but I had never run one, so I couldn't very well put them on it until I ran it myself; they might kill themselves or break it.

Swent: When did they come in?

Reed: During that three years that I was in the mine.

Swent: Late forties?

Reed: Yes, about 1946 or 1947.

Swent: What kind was it?

Reed: A regular old EIMCO air-powered overshot loader, perhaps a 12-B. You hooked a car behind it and then ran it into the muck pile. Of course the miners thought it was the last word.

Swent: It was a wonderful help, wasn't it?

Reed: Oh, yes. Hand mucking is not that easy. That was one thing about the mine that really did get to me--that when you thought of a better way of doing something, or you knew there were much better ways to do it, they weren't interested. The mucking machine took a long time. In the development stages a scraper would have been so easy and so obvious because of all these *buitras* in the floor that I've been talking about.

Block Caving at El Teniente Mine

Reed: When you're developing and shooting the rock down to make the draw chimneys that go up--do you know how a block caving system works?

Swent: A little bit, but you tell me.

Reed: You're working at a great big block of ground, say in the hundreds of feet square--300 to 500 feet square, say, and 500 feet high--to start with, and it's a solid block of ground. You go in underneath it on the production level, and you put like parallel streets in; every twelve meters--forty-foot centers--there's a street going under this big block of ground.

Swent: But you don't call it a street.

Reed: No, you call it a drift. They are all numbered, so you know where you are. After you get through putting the drifts in, you timber them with sets at five-foot centers--big twelve-by-twelve sets.

Swent: These are the timbers?

Reed: Yes. In the beginning, when I first got there, they were twelve-by-twelve sets. What you are going to do with this great big block of ground is take a horizontal slice out of the whole thing underneath and leave it completely unsupported. Now, you don't do this all at once; you nibble at one corner and retreat across the entire block. But ultimately that great big block of ground is completely undercut, and probably weakened on the sides with some raises, so that it breaks itself up by the load on it. On top of it, up there anywhere from three or four hundred feet above to maybe six hundred feet above, was the previous production level.

This whole thing started in the side of a mountain, near the top, and they undercut the first level right up under the top of the mountain and did this block business. Of course, it caved right through to the surface and left a crater full of broken rock up at the top. Then through the years they increased the area of this undercut level until they got to the edge of the ore where the grade dropped to 1 percent copper. The ore was deposited in a crescent shape around an old volcanic vent which had punched up through the volcanic country rock. This fractured the country rock around the vent, and the fracturing let the mineralizing solutions in. So the ore body became a crescent lying around this pipe. It was highest grade near the pipe, where the cracks were the biggest, probably, and it tailed off out into the wall rock. The structure was all vertical, but we called it, just for nomenclature purposes, the hanging wall against the pipe and the foot wall way out in the country rock.

For example, when I first went to work on B North North Level, the drifts were numbered from Five Right, which was towards the hanging wall (Five, Four, Three, Two, One) towards the footwall, and then Barrier Pillar; that was the name of the drift, even though there wasn't any barrier pillar there. Then it started up One, Two, Three, Four Left. Well, it went from Five Right to Eight Left, which was the farthest out in the footwall. Let's see: eight and five are thirteen, and one more is fourteen, times forty feet, so the total area being worked was about 500 feet square. [see appendix, vertical section maps of Braden Mine, Figures 1, 2, and 3]

As a block is mined, all its chutes are sampled periodically and assayed. In my time, when the grade got down to 1 percent copper, then they closed the chute. Up here [in the U.S.] we start

mines now with half a percent copper, but in Chile in 1945 the ore grade was something over 2 percent. So they stopped; they closed the chutes, in other words, at 1 percent. When that whole level had gotten to 1 percent, then that level was finished and they'd go down, say, 300 to 400 feet and start a new level. In the middle of this extracted area they would undercut a block. After they got it going, they would undercut adjacent blocks and gradually work outwards. They'd work around the crescent to the extent of the ore, and then the same thing would happen again on the next level down.

The mine was started near the mountaintop with J Level, and the level interval was perhaps fifty meters. When I came along in 1944, I worked on B level, which was the top production level. Teniente One was a hundred meters (328 feet) below.

To get back to this block, you get these drifts underneath it first, and the sets are in there every five feet. In the beginning they used to undercut directly on top of the timber. In other words, they'd put a chute in every space--the *claro* is the four feet of space between the sets--alternating first on one side and then on the other side. It made an awful lot of chutes, of course. The undercut was an inclined slot joining the chutes on each side of the drift and rising towards a crest halfway to the adjacent drift, where it met the slot rising from that side.

Ultimately they had that whole thing undercut, and they would retreat, gradually undercutting it, and the rock would get heavier and heavier and start to break up. Then you would try to keep pulling it out through the chutes. However, by the time you got all the timber in the chute was about three feet wide and about two feet high. You hoped the rock would crumble up in little pieces that would come out of that chute, but in the beginning it didn't; big pieces came down, and they would land right on the chute like a big cork. There you were, staring at a boulder. You couldn't go up there anymore, so you would drill a hole in it--that's where the *buzonero* came in, a man with a little hand drill--and blast it. Of course, that proceeds to break the timber up if he's not careful.

So you're constantly fighting to get the rock out. If you don't keep the rock coming out, then the weight builds up, and the timber suffers. It was a real constant battle. By the time I came along we still had some areas like that, but they gradually began to change the system. Now they decided to leave a pillar of rock over the production level and undercut on top of that pillar. The pillar was about eight meters thick. So the floor of the undercut level was something like twenty-six feet above the floor of the production drift. With the pillar to protect the timber in the drift--take some of the load and transmit it down--they went to

eight-by-eight inch timber sets, which was a big saving in the timber. Now, timber really never was supposed to take weight, as long as the pillar held.

Swent: These were eight-by-eight sets?

Reed: Correct. A set is basically two posts and a cap--the bridge across the top of the posts. With this new system with the pillar, the hope was that the pillar would never break. If the pillar never broke, there really never would be any weight on the eight-by-eight sets. They would serve the purpose of safety and mounting the chutes and so forth, but you really hoped that no weight ever came on them. They wouldn't hold much weight; if the pillar broke, they got crunched right now. Then you would immediately switch. What it would amount to was that you'd take out the eight-by-eights and put in twelve-by-twelve sets and go back to the old system. But it didn't happen very often. It was pretty good, then. The drift was about seven by nine broken (driven) through the rock. When you put the timber in, it got down so that you had about four by six and a half clear inside the timber through it.

When they went to the eight-by-eight timber, they also used a chute only in every other set. From each chute went out a little raise laterally from the drift, then vertically, and finally opened up into a funnel as it reached the floor of the undercut level. When you got all done, it was as if you had a big box of sand with a bunch of corks in holes in the bottom on a uniform grid. That's really what it was, because the chutes were either on one drift or the next drift but uniformly distributed. As fast as this big block of ground would break up and rattle down, you'd draw it out. You'd just pull the cork and open the chute and let the sand out. The idea was to pull the broken ore down uniformly, because if you started to pull too much at one place you would pull the waste rock in from way up above somewhere and dilute the ore. The idea was to bring it down uniformly and not get it diluted. Constantly, in the whole mine, there was a bed of less than 1 percent rock (waste) sitting on top of active ore. This waste was all broken up and was following you down. This crater in the top of the mountain got really tremendous--about a mile across--after while, this had been going on so long.

That was basically the mining system, and it was all very systematized.

##

Swent: You had mentioned the Braden Bible yesterday.

Reed: Yes, we all had a copy, and we were supposed to know everything in there by the numbers. You just didn't use any initiative to change anything. If you changed anything, you answered for it. For example, in the new drifts, with a *buitra* every fifty-five feet, a scraper mounted on a flat car would be so easy and effective in cleaning up after the many little raise blasts in the chutes. Mines in this country all used scrapers; they didn't put tracks and cars in. It seemed like an obvious improvement, but it never came to pass. They never used scrapers there.

Swent: They had cars and rails?

Reed: Yes, one-ton cars. The cars had an odometer underneath that registered every time you dumped the car. It had a weighing system in it, and it wouldn't register [unless there was weight in the car]. It was an incentive system, as I told you, and a man was paid at the end of the shift by how many cars he'd pulled and dumped. To get the number, you tipped up the car and read the odometer underneath. But you couldn't jimmy it, or you weren't supposed to be able to; unless you put a full load in the car, it wouldn't register. And there were car checkers; that was their business. All they did was walk up and down the drift and read the odometers on every car before the shift started. They'd make out a little slip for that car-man, with where he started and where he finished, at the end of the shift. The difference was how many cars he got paid.

If the chute was pulling easy--and sometimes it was like sugar, and the trouble was stopping the chute; it would just run, and the car would fill in a minute. The chute boards slid in slots--it was a very crude system--and you'd put a pry bar under the board and slide it up in the slot so the rock would slide out. When you got the car full, you'd have to beat the board down to shut it off. If you don't get it shut off, it overflows the car and it's all over the ground, and you have to shovel it up. So the car-men (*carreros*) get adept at this.

If the muck was running easy, then the price per car on that chute was set accordingly. So you might have to pull a hundred cars in a shift to make *sueldo*, or base pay, if it was an easy chute. But if it was near the hanging wall and early in the history of the block, you might just be fighting to get five or six cars out of that chute because you'd have to drill and blast almost everything that came out. Then maybe only fifteen or twenty cars would be a hard day's work. Yet, I've seen guys get paid for two hundred or three hundred cars. Out in the foot wall the rock would break easy and grind up into this fine stuff like pea gravel, and it would just run like crazy. Those guys were just running up and

down the drift dumping cars like a track meet, because they went so fast.

The other thing about such free-running ore is that once in a while the car-man wouldn't get the chute shut off, and he'd fight, because he knew he had to clean up the overflow. So he'd be up on the step board, the *pisadero*, a plank that was on a couple of cleats on the two sets opposite the chute. The car puller stood up on this little walkway right in front of the chute so he could work over the top of the car and pull the stuff down.

There have been cases where somebody comes walking along the drift, and here's a car-man who fought to stop that chute until it overflowed the car, filled up to around his knees, and actually had him anchored there. He was still fighting to shut the stuff off, and it would finally shut off when it was chest high--him and the car and the whole bit. It was a great big pile of pea gravel. It hadn't snuffed him out yet, but they might have to dig him out. That didn't happen often, but that was the potential.

Pulling these cars--you can't believe thirty thousand tons a day doing that. When I got there they were just getting around to the idea of what they called direct draw, where they put up more chimneys from below into the drift, like an upside down tree of raises, so the *buitras* were closer together in the drifts. In fact, it ended up that there were no cars at all in the production drifts. Right at the top of the *buitra* there was a chute on both sides angling off at forty-five and then up to these funnels. Instead of a car-man you had a chute puller. The chute was right there at the side of the *buitra*, so you just opened that up and let it run directly into the *buitra*--a direct draw. Then the productivity went up tremendously. The development or capital costs in getting this whole thing started were maybe a little bit more because there were more raises, but from then on one guy could draw a couple thousand tons in a shift. That's the system that's being used there now.

Swent: Were the cars motorized?

Reed: No. They were one-ton end-dump cars. You faced the car towards the *buitra*, backed up to a chute, filled it, trundled it over, and dumped it in the raise.

Swent: The men were pushing the cars themselves?

Reed: Yes. It was all perfectly level. They didn't push very far. It was peculiar; in the eight-by-eight sets, there'd be a chute in the very first *claro* from the *buitra*, so there they pulled it into the car and didn't push it anywhere. They pulled it in with the car

here and just dumped it right there. The next chute up would be about fifteen feet away, so it was a short tram. The third one, the last one, would be about thirty feet. Then they'd turn the car around and go to the other *buitras* down the drift in the other direction. There was no place or no need for a motor to push the cars. It wasn't like a train; it was only one car between each *buitra*.

Learning About Rock Mechanics

Swent: This is where you began to learn about rock mechanics?

Reed: Yes, as a matter of fact, that's exactly where I learned it. I spoke of this pillar--

Swent: Someone must have innovated that.

Reed: Oh, yes. They looked up here [in the U.S.]. Up here they'd been using pillars to protect the sets for years. But they were very slow to change; that's the point.

I came along and got a taste of both, and I could see--everybody could; it wasn't just me--that the eight-by-eight sets and the pillar was the way to go. There are drifts going north and south, we'll say, and crosscuts go east and west, and they connect at all the drifts. So once in a while you have a crosscut, but not very often; not every forty feet, but only at a convenient distance apart just for access into all the drifts. Those crosscuts were always carried out ahead of the undercutting in the bare rock. Out in the open rock you didn't have to timber anything; for a long time the rock was self-supporting. It was only when you had undercut over the top of it and got the weight going that you had to have timber in it.

So the development work was always done ahead. The miners were running the drifts on out into the solid, and once in a while a crosscut would connect them. It might be two or three years of production before the undercut got out that way, and then they would be timbered. Incidentally, that's not a very good idea, because the rock does kind of deteriorate with time, but that's a minor thing. Eventually, though, as you start to timber and undercut, you're going to go right over one of those crosscuts, and you don't want to maintain that crosscut, we'll say. So you fill it up with the rock and go ahead and timber. After you get through you wouldn't even know there was a crosscut there, but the rock still knows a crosscut was there. That band of rock, in a line

across all the drifts, is a weak zone. So when the weight comes on and you've got the eight-by-eight timber in there, that's where the pillar's going to fail. There'll be just a short section, maybe four or five sets, where the pillar will actually break, and those eight-by-eight sets will take a great crunch all at once. Then the rule of thumb was to jump in, tear them out, and put in twelve-by-twelve sets. And drill all this broken pillar over your head, which maybe is one great big block of ground and still pretty much intact. But break it all up, blast it out, and go back to the old-fashioned system of relieve, relieve, and so forth, and fight.

Swent: You had time to do that? It didn't collapse?

Reed: It would move, boom, just overnight perhaps, and all these eight-by-eight sets would be telescoped a few inches. But then it would quiet down, and in a week or two you could go in and tear all that out and put in the twelve-by-twelve sets. I looked at that--and this was one place where I tried to innovate--and it got me into the rock mechanics business. I thought to myself, once you undercut and chew that block of rock up, then you've got, forever more, this problem of relieving and trying to save the timber. Maybe if you just helped the timber to hold the rock, it would reconsolidate and you'd still have a pillar over your head, though it might be a little bit lower.

I didn't do it on my own, but I argued and got them to let me try it in one of the drifts. I think we put in the twelve-by-twelve sets all right, but then we put between the twelve-by-twelve sets in that heavy space another twelve-by-twelve set. So we almost had solid timber of twelve-by-twelves, and we did no relieving--they called it *descargando*, from "*descargar*," to unload--to unload the rock behind. In other words, let it all consolidate and take weight again, and I figured it would hold. Indeed, it did hold. This is where I guess I first got the idea of helping rock to carry its own load, even when it's on the verge of not being able to be self-supporting. Help it a little bit, and maybe it would. Eventually that got to rock reinforcement, which has been my specialty. That's really where I first got the idea.

Swent: This is something that hadn't occurred to anybody else?

Reed: Oh, I don't know, I suppose other people had thought about it, but this rule of thumb was always to go back to the old system and undercut and relieve it. It was highly labor intensive. There's a little sequel to this [laughs] that put the kibosh on some of it. By the time you have twelve-by-twelve sets on five feet centers, you have a four-foot space in between. Then if you put another twelve-by-twelve set in that four-foot space; that leaves three, so now you've got only eighteen inches between the sets. Well, if

it's all been squeezed down a bit and you've got a one-ton car coming through the drift, there's no space for you to get by the car; you've got to hop up in that little eighteen-inch space and get yourself out of the way--if there's a loaded car coming, for example, and you're just walking through.

I haven't talked about the blood lines of the people in Chile, but it's a bit like America. Whereas Peru is full of pure Indians and a lot of Spanish type people, in Chile there aren't a whole lot of pure Indians left. The general population is a blend of Spanish, Anglo, and German ancestry, with a few pure Indians, but not very many.

When I had a big crew, there would be some miners with Indian names, and some of them were pretty pure. Really, I found that some of those pure Indians were the most dependable workers I had. The Indian fellows, if I were good friends with them, were very dependable. If they said they'd do something, they'd do it. Or if I told them to do something, they'd do it that way; they wouldn't beat about the bush.

I remember one old timberman I had who was one of these types, and I kind of liked him. He was coming down the drift one day, coming out from where he was working with his timber, I guess, and he was in one of these narrow places where we had doubled up the timber. Along the drift came a guy with a carload of rock. He's highballing along, pushing, so Mr. Timberman has to get himself out of the way. He climbs up in this little slot and is holding himself up in there. Their lunch, which they called their *choca*, a sandwich wrapped in paper, they usually carried in their shirt. There was no such thing as a thermos bottle, but they'd also carry an old whiskey bottle or a flask in which they carried their tea. He had his *choca* in his shirt, but he had his tea bottle in his hand. I'll be doggoned if he didn't get himself out of the way and was holding himself up, but the hand with the tea bottle was down too far. The car caught it against the set and crunched his hand and the bottle in his hand. He got over it, but it gave him a bad cut and really buggered up his hand.

Now, there was an accident you could point at--he had no place to go; in that thirty or forty feet of drift there was no safety place. That put an end to that whole idea; you don't ever do that again. It worked from the point of saving the pillar, but it created a safety hazard. The idea was worthwhile, but the system wasn't ready to utilize it.

Swent: We haven't talked about the fire yet.

Reed: Let's finish the *practicante* period first. You did spend some time with a miner, driving a drift. One thing they didn't do, and this has to do with the fire--there was very little--almost no--effort at making the new man acquainted with the whole mine and how it was all tied together, and where you could communicate. The whole idea was so systematic: you got this Bible, and you were aimed at production. You ended up on a production level, and that's all you saw. It took an hour to get from town into the mine in the first place, and you went right to your production level. You were there eight hours, and it took you an hour to get home, so you put in a ten-hour day. You didn't know where the rock went. Once you put it in the *buitra*, it was gone. It actually went fifteen hundred feet down connected raises and was pulled out in a mainline railroad car and hauled out to the mill. But you didn't have much knowledge of all that, and you had no idea of alternate exits. Nobody had been thinking about alternate exits, and none were marked.

What I'm saying is that there was a weakness there. I think a man would have worked better, and been a more useful production employee, if he had a better idea of how he related to all the other parts of the mine. A little more of that would have been a good part of the *practicante* period. As it was, I think you spent one day on the lower intermediate-draw control levels with a boss, and you walked around with him through endless drifts, of course--the distances were great down there--and you saw half a dozen men. It was a sparsely populated part of the mine, though very important. This great tree, if you will, with all these branching raises went down, and they got bigger and bigger but fewer of them as they went down, until they were huge raises full of broken rock. They were controlled every hundred meters or so until they got all the way down fifteen hundred feet to the bottom.

Well, you got only a very brief introduction to that, and that's where everybody had to go when they tried to get out during the fire, and they weren't familiar with all that. I think that general mine familiarizaiton should have been included in the *practicante* period.

So you worked with timbermen and the miners, and that's about all. At the end of the three months you were given a good head *cabo* to back you up, as I spoke of, and the full range of *cabos* under you, and you became a shift boss and went on three shifts a day, rotating every two weeks. All the *practicante* period was on day shift.

Swent: There was always room for another shift boss at the end of the *practicante* period?

Reed: Yes. I don't think I ever, in the time I was there, saw a time when we had a full complement of gringo shift bosses. It would have been maybe four levels, so that would have been twelve gringo shift bosses. I don't think there ever were twelve gringo shift bosses there, so some of the spots were being run by a good head *cabo*; he'd be serving as a shift boss. The hierarchy there was that a shift boss just had to do with production. You worked with the timbermen and the car-men. You didn't have much to do with the miners that were actually driving development; that was the assistant mine foreman's job. The shift boss took care of the ore production and the timber maintenance on the level.

The person in charge of that area was called a mine foreman, and he was really a section foreman. Starting at the top, there was a general mine superintendent and his assistant, and then there was a general mine foreman and his assistant. They were all over the entire mine, including about four production levels, but each one of those production levels was also called a "mine," in a different sense. It was really a level, or section, but the man in charge, who was totally responsible for that area on all three shifts, was a mine foreman. Under him was a level foreman, whose primary job was nothing but the timber maintenance. That shows how important it was. He was straight day shift; all the people I've mentioned down to the level foreman were straight day shift. Only the shift bosses and assistant mine foremen rotated shifts.

The level foreman walked around daily, and he knew every stick of timber on that level by its first name. I don't have any examples of our timber repair shorthand notes, and I've been talking to some of the other ex-Bradenites to try to get examples. You had this little notebook, and as you walked the drifts, every time you saw a place that had to be a major repair place, you wrote up in shorthand what was going to be about three lines, closely-spaced typewritten, for all the timber work that had to be done, step by step, at that particular position, for the next twenty-four hours. That's what it amounted to. That was a crew position, the crew being the timberman and his helper.

You walked around and wrote up in your little notebook. In one drift where it was heavy and closing in, you might have six or eight crews lined out in your notebook. You did all this before lunch. You made a round--up one drift and down the other. Meanwhile, your boss, the mine foreman, was basically doing the same thing but keeping an eye on you. Of course, he only put his mind on the really critical parts, mostly. When you both got back to the underground office and sat down to eat your lunch, all the time you were eating he was going over his notes with you, or the other way around. If you were the level foreman, you'd be reading off, "In Drift Seven Right of Set 87-8, this is what I've got," and

he might say, "Well, that place is getting bad. We'd better do something more serious there." So he'd edit what you had, in other words. But then he might go right along with you on all the other things.

When you had finally gone through all of it, then you had a line-up there for maybe forty or fifty crews. Well, you never had but about thirty; the number of men who actually came in was changing every day. You two were sitting there, looking at your notes, and the next thing you had to do was put a priority number on each crew. When the men came in and the *capataces* were assigning the crews to their work, they would go by those priority numbers. So number one crew might be in Three Left; number two crew might be over in Four Right. When your final letter was typewritten, about three or four pages close-spaced, the whole schmear, it's just one crew after another, arranged by drifts--all the crews that are in Five Right, Four Right, and so forth. But then these priority numbers are all over the place.

At the beginning of a shift, the head timber *cabo* would size up how many crews he had. He might have twenty-five crews that day. He'd pick out his best, most capable timberman and assign him to *nombrada* (priority) one, wherever it might be. Then he'd check that off and look for his next best timberman and send him to number two, and so forth. When he got to twenty-five, the rest of the letter just got ignored that shift. When the next shift came in, that *cabo* would hand the letter, with all the work done checked off, to the next *cabo*, and he'd use it. In other words, for three shifts it got used. By that time it was the end of the day shift, and they got a new letter.

The level foreman is getting all this priority at lunch on day shift. As soon as he gets through his lunch he's got to get busy typing it on an old mechanical typewriter, of course. Most of us didn't know how to type, so it was seek 'em and sock 'em. I never learned to type properly. You had to get going to get this letter typed, because the afternoon shift was coming in, and you had to have it ready for them. That's when they got it new, and that was at about three o'clock. So you had only about an hour to type up these three or four pages. Very often you wouldn't have the last page typed, and they'd be in there. The pages would be going out to the *cabos* as you finished them.

This timber letter was a very interesting thing, and I'm so sorry I haven't got a sample of it. Even the shorthand I've forgotten. I still use some of the terms. This little symbol, two vertical lines like a number 11, I think meant "place" or "put." But the same thing with a line across it meant "change." For example, would be "change the set," and then you'd have the

number of the set after it. Still, in my own little notes today, if I want to change something, that's what goes down. But I can't remember all the symbols. Lou Carpenter was a mine superintendent starting about when I left, and now he's retired over in Ridgecrest, California. I went to visit him recently, and he's put together some from his memory; he doesn't have an example, either, but he's fresher at it than I, and he's given me some things. I might be able to get that to you eventually. It was a shorthand, and you could say a lot in one typewritten line.

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Swent: So you learned to type?

Reed: Right. I got pretty proficient at that eventually, by necessity. Anyhow, that was the basic job of the level foreman.

Swent: What was your personal progression?

Reed: I was a shift boss until the time of the fire. That took out one whole level of gringos; a mine foreman and his assistant, and a level foreman were the three gringos who died on Teniente One in the fire. Immediately we spread out, and that's when I got elevated to, in effect--of course, my B North North level was the first place where they had gone to the eight-by-eight timber, so that level had a lot less of this heavy timbering work to be done. So they kind of made me into an unofficial level foreman. In fact, I was the only guy on the level; I was the level foreman and had a Chilean working, in effect, as a shift boss. There was no mine foreman around, I remember, for quite a while, and I was doing everything by myself on that level because of this stretch-out in the staff available. Ultimately, though, I became a level foreman officially, and I ended up down on Teniente One level, where the fire had been.

The level foreman normally takes care of the timber, and he's got a mine foreman right there at his elbow making sure. The next step up is assistant mine foreman. In theory there would be an assistant mine foreman, or maybe two, on each level. Practically, it turned out that there was usually only a couple of them in the whole mine. In the daytime the assistant mine foreman's primary responsibility was to look after the miners; when we speak of miners we mean drill and blast miners, the fellows who broke the rock. If there were any development miners, you might have half a dozen of them driving drifts or raises or something else, and you had to see them first thing every shift and make sure they had their center line marked and knew what they were going to do that day.

If there was any undercutting going on--there was usually undercutting only on one place in the mine at a time, and sometimes no places, but there would never be undercutting at three different levels at the same time because you only had, really, one good crew of undercut miners for the whole mine, and they rotated around. They did one of these blocks of ground here at B North North one time, and then they moved over to B South and did something there.

Drilling and Blasting

Swent: What kind of equipment were they using?

Reed: In all the mining at that time there was no such thing as a jumbo. We used the old-fashioned column-mounted machine primarily. It had a big screw jack column, like a piece of heavy pipe about three or four inches in diameter with a screw jack in the bottom of it. You stood it on a big block of wood on the floor, and the top of it went up against a block against the ceiling rock. You'd turn a screw jack in the bottom of it and jack it out against those two blocks until it was rigid and mounted properly. Then you put an arm on that, which is about two feet long, and clamps around that pipe with a locking bolt. Wherever you slide that up and down the column and lock it, there you have this arm sticking out. On the arm is a saddle which also clamps on the arm, and the drill sits in that saddle, and you clamp that. So now you can loosen that and point the drill anywhere you want to--up, down, or sideways. You put the whole thing up at the top of the column to start with, and you drill the top holes in your round. Then you loosen the clamp on the column and let it slide down about a foot, with great care because you've got a couple of hundred pounds on this thing, and you clamp it up again and drill the next row of holes. Finally, you end up at the floor, drilling the lifters. It's a real old-fashioned way of drilling, but that was the standard development system, and also in the undercut.

Swent: What kind of explosive were they using?

Reed: I guess you'd call it gelatin dynamite. It was before what is now common, ANFO, bulk-loading ammonium nitrate fuel oil. That hadn't been thought of yet.

Swent: It wasn't sticks?

Reed: Oh, yes, it was sticks, but it wasn't just straight nitroglycerin dynamite. It did have nitroglycerin in it, because you got dandy headaches. It was what I think in those days would have been called gelignite; it was gelatin dynamite.

Swent: What brands did you use?

Reed: Sometimes we got it from the States; I can't remember what company. Mostly it was made in Chile. You remember the nice old wooden dynamite boxes?

Swent: Powder boxes.

Reed: Yes. Everything was made of powder boxes--bookcases and everything else. We treasured those boxes. In fact, I particularly treasured the U.S. ones because it was much better wood. I made all kinds of things in the staff house and around my home, when I had a home there, out of those boxes. They were very useful.

Anyhow, the drills were all column-mounted or stopers; a stoper is an air cylinder with a pneumatic drill mounted in line on the top of it. It's for drilling nothing but holes angled upwards, as in a raise. A man has to stand there and hang on to it so it doesn't spin around; it's a self-rotating drill. In drilling the raises, the miners all used the stoper, and in the undercuts they used a big leyner drill,[1] a heavier column-mounted one--about a three and a half inch machine. The undercut was an array of horizontal holes, but at the same time, in order to get this big block breaking up, there would be a couple of guys in there with stopers drilling holes about seven feet long up into the roof.

Undercutting was quite a thing. It could be hair-raising. We're working on a pillar system now, so you climb up through one of these raises about twenty-five feet on a ladder. Everything had to go up there on ladders and be pulled up with ropes; there was no such thing as a hoist. So all these heavy machines went up there. Now, you climb up, and first off you're just in an undercut drift, which is about six by seven feet. The undercutting has to be done in a very systematic, timely fashion, because that rock is beginning to break up. That's what you want it to do, but you want it to stay intact for about two days while you're in there. Then you're going to blast the dickens out of it and hopefully leave nothing but broken rock behind you, with no remnant pillars. You never go back in there again, of course, if the last blast did its job. And there's no timber up there, only temporary individual props called stulls.

You climb up the raise, and you're in the undercut drift which leads you to the far corner of the block to be undercut. The first day's job is to widen the end of that drift to twice its width; that's called a *desquinche* in Spanish. The *desquinche* blast is getting that twice as wide, and the *polvorazo* blast, if you can imagine what that would be, is to make the whole thing into powder.

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[1]After John George Leyner, the inventor of the hammer rock drill.

That's the last blast. You're doing this on a retreating system. Everyday you're blasting one polverazo blast against the previously-undercut ground. At the same time you're in the next drift over, blasting a *desquinche* blast so that tomorrow you can do the *polvorazo* blast in that place. The pillar of rock that's left between the *desquinche* and the *polvorazo* is about twelve feet thick, so you have to have a space for a twelve-foot drill steel to drill a hole that deep. If it were in the drift without the *desquinche*, the longest steel you could put in would be six feet long. So you need to get the *desquinche* blast made at the same time so that the next day you have space to drill the next *polvorozo*, or final blast.

You've got to do all these things in steps and never miss a step, because if you say, "We didn't make it today; we'll do it tomorrow," the damned thing's liable to be down tonight. The only thing to control the rock in the undercut level is a few stulls that are put in. A stull is just a round tree trunk about six to eight inches in diameter, not framed or anything. It's about seven feet long--just long enough so you can put a block on the ground underneath, stand it on the block, and put a second block--a headboard, a piece about twelve-inch by eighteen-inch, about four inches thick on top. That just about reaches the roof, and then you fill in with wedges and tighten it up as tight as you can.

This stull is just sitting there for moral support, to start with, but if the rock is really moving down, as it probably is, it'll start to tighten. Pretty soon you'll see the round timber beginning to bite into the block at the head, and then you know it's snug and not going to pop out at you. You hope it's going to stand the gaff for two days until you get out of there.

This is all a very intensive, time-scheduled business. The *polvorazo* blast--the intensive drilling and so forth--ends up being in a room about twelve feet wide and probably thirty-five feet long. You've got about six of these great big leyner machines in there drilling this array of holes--six miners all going at the same time, drilling both sides with twelve-foot holes, which is going to take all the day shift. In addition, you'll have maybe two guys in there with stopers trying to drill the back of this same room entirely full of holes. You're all up there through one little manway about twenty feet high. There's a hell of a lot going on, and the noise is unbelievable. All those rock drills going full bore--it's not only noisy, it's pulsing the air, all the compressed air coming out, all the exhaust and everything. It's full of fog, because the expanding air is cool and it condenses and makes a dense fog.

So here you are, with at least eight guys drilling like crazy, and you're in a fog so thick that you're wandering around in there just by feel. There's no talking to them because of the noise.

Swent: What was the temperature in there?

Reed: Oh, comfortable, usually. There were a few hot places, but mostly not. It was sixty-five or something like that--just basically cool. Once in a while you'd get in a place where it was hot, where the ore was oxidizing and generated a lot of heat, but mostly it was just temperate.

This undercutting business could be a traumatic experience, all day on day shift. If that were going on, the assistant mine foreman on that level was there *fijo*, as we said--fixed. He was there with those miners the whole eight hours to be sure there were no delays and that nothing went wrong; it was high priority. The undercut was the highest priority on the level when it was going on, because you had to not only get it all drilled out, but then all charged with dynamite. And an awful lot of dynamite went into that thing--all you could stuff in. As soon as you got one miner through drilling, there were powdermen up there charging the holes. While the other guys were still drilling, you had guys up there with the dynamite going in. If you were lucky, you got the whole thing done at the end of the shift. Then you had to spit--light--all those fuses.

That's another thing--this is where safety suggestions came in. The first time I saw one of those undercuts, early on, one of my recommendations--and I've got a letter to the foreman or general superintendent here--was that we go to electric blasting <u>at least in those undercuts</u>. Because it was a traumatic thing to light all those fuses. Not only was it a safety matter, I am convinced (and I'll explain why) that many times a lot of those fuses never got lit, and that meant that the blast was not effective, because the holes were dependent upon each other. Each row of holes was supposed to go off ahead of the one behind it. If some of them didn't, then the one behind didn't have any relief to break to, so the rest of the round maybe was ineffective. The next day when you came up there and looked out in that space where you weren't supposed to go, here was a pillar still out there that had not gotten broken. Then you had real bad trouble; somebody had to stick his neck out and go out there and maybe drill it.

To get back to the system, at the end of the shift you've got literally about a 150 fuses to light (spit). There are at least three sticking out of each row of holes every meter down the wall on each side for this whole thirty-five or forty feet, each with a fuse hanging out of it. All over the roof about every meter is a fuse hanging out of the roof, and those all have to be lit. By this time the fog has cleared away, but you know that as soon as you start lighting those fuses, they make an awful lot of smoke. So before you're anywhere near done, you're up there in a completely impenetrable fog of smoke.

There's only one ladder out, and you want to be sure everybody gets out of there. The holes start going off about the time you get to the bottom of the ladder. The shortest fuse in there was only about seven feet. [figuring] Seven times forty seconds is twenty-eight--about four minutes from the time you start spitting, some of those things are going to start going off. I don't think we cut many of those fuses to length up there to time it. We'd start where we wanted to start breaking, where there was some relief, and we'd work our way back towards the solid, lighting them. The time it took to light them was the time delay they were going to have. I know it was always a hell of a mental strain to think about--

Swent: What did you light them with?

Reed: With something like a Fourth of July sparkler and called a hot-wire lighter. It doesn't sparkle all over; it just glows, but it looks just like a sparkler. It's a wire about a foot long, with half of it covered with this compound. Once you light it, it glows. Incidentally (I'm glad you brought it up), it only burns so long, and then it runs out of this compound and will go out. They're kind of hard to start. You'd start it with a carbide light, which you had. You had a lot of this to do, so you had a whole bunch of these hot wire lighters hooked in the buttonhole of your shirt. You might have half a dozen of them. As soon as you saw one getting down to the end of its five- or six-inch compound, before it went out you wanted to pull out another one and light it from the first one. They light each other very easily, but they're stubborn to light with a carbide light, and you didn't want any stubborn business at this point. Every second counted.

You were responsible for this, and you were concerned. If you took five guys up in there, then each one would have fewer fuses to light, but you had to remember how many guys you had up there and get them all out of that smoke.

Swent: And out of a very small manway.

Reed: Yes. So it was a give-and-take thing. You wanted some help, but you were determined that you were going to have a minimum of people up there with you so you could keep track of them. It was always a real hassle. As I said, you'd start at the other end, and one guy would do all the shots on one side of the room, you'd do all the shots on the other side, and you'd put a third guy maybe trying to do all these ones hanging out of the roof. But finding the damned things in the smoke, so thick that you could hardly see! You were just feeling your way around. I'm sure we missed a lot of them. But as you came out, you'd light the center hole on the wall, then probably the top hole, and then the bottom hole. Then you'd go to

the next row and find the middle hole, the top hole, and the bottom hole, and so forth. That was pretty systematic.

Finally you'd be sure you got all the men down the ladder ahead of you, and then you went down the ladder.

Swent: Like the captain of a ship, you got to go last?

Reed: Right. And you hoped to beat hell that you had everything lit. But if you didn't, there was nothing you could do about it. At the same time, somebody was in the *desquinche* drift lighting the whole row of holes in there, too, because that was the next one over and was going to be the *polvorazo* place for tomorrow.

This all went on at the end of day shift. The afternoon shift that were coming in right away were supposed to go in there as soon as they could get enough air through the production drift beneath, and blow the smoke out. Of course, there was a hellacious lot of smoke. There were hundreds of pounds of dynamite involved, so you can imagine--all those holes tamped full--so there was a lot of smoke involved. The afternoon shift were supposed to pull all the chutes underneath, because of course there were chutes on a checkerboard under this whole area that you just blasted, and it was all full of broken rock. You had to pull that down two ways.

First, you wanted to pull the *polvorazo* part of it down so somebody could get up there the next day and look in to be sure there weren't any pillars left. Then on swing shift, a shift that came in at eight o'clock until four o'clock in the morning, was the assistant mine foreman on night shift. His primary job, when there was an undercut going was to get in there and get the *desquinche* area ready to drill tomorrow's *polvorazo*. This required pulling the blasted rock down to the right level for a floor and then getting in there with timbermen to bar it all down safely and get the stulls in--in other words, to make *cancha*, as they would say. You speak of a *cancha de tennis*, so a *cancha* is your playing field.

The playing field for the next day was the *cancha* that you made in this widened drift, and that was what was going to be the *polvorazo* blast on the day shift following. It was very important, high priority, that the guy on night shift got that done, regardless of what else got done. He had to leave that ready, *sin falta*, so that the miners the next morning could get right up there at work, because they had to get done in a day, too, you see. This was all very high priority, and the assistant mine foreman was the mine foreman's helper on day shift to do the drilling and the blasting, and on night shift to leave it ready. You could take anybody off the level from anything else to get that thing done on the night shift. You had the authority there.

Swent: Was this a job that you had?

Reed: That's what I ended up doing. My highest level in the mine was assistant mine foreman.

Swent: It was a tremendous responsibility.

Reed: Well, it came to you. By that time I'd been there nearly three years, so I had a lot of chance to learn the ropes. But it did turn out that in my time at bat on the night shift I was sometimes the only gringo in the whole mine. I was supposed to go around to all three production levels and sign the time cards for everybody that was on the graveyard shift, for example, and B shift also--because I was on split shift. That was a unique experience. You'd be running around, and each mine foreman would leave notes for what to get done on his level, and he'd be telling you this same thing, "*Sin falta*, get this done." And here you are, one guy who's supposed to go twice a shift to all three levels and see about everything. I don't think I ever had an undercut going on during my times alone on night shift, because you couldn't have gotten it all done.

Speaking of leaving notes for the oncoming shift, this was the situation with the fellow that was on swing shift. He didn't talk directly to the people on day shift because he came in four hours later, and he went out four hours before they came in the next morning. So the only communication with him was through the notebook that was left in each level office. That sometimes got kind of ticklish, because you'd write down what you had gotten done on the level that time, something that maybe was very important. You'd write down what you had managed to accomplish, and the mine foreman reading that is only thinking of what you did on his level. But in the meantime you had had the same sort of thing on two other levels. He might get pretty caustic in the way of notes about what he left for you the next night.

Sometimes there were misunderstandings. One particular exchange of notes I remember. There was this great gob of broken rock, ore and waste, in this huge conical cave system that was over all the workings. It was all broken rock, so the spaces between the rock were full of air. Air is 79 percent nitrogen and 21 percent oxygen, roughly. All this rock is full of sulfides, and the sulfides are oxidizing. When they oxidize they use up the oxygen in the air. So really what this great gravel bed is full of is nitrogen, or oxygen-deficient air, if you will. Down in our production level drifts, when they dead-end and the timber gets crunched, you're working back out of that and have to work in there replacing the timber and pulling the chutes. You haven't got the chutes down to cut off grade yet, the 1 percent I spoke of. You're always retreating, and yet you're always fighting to keep that drift up until you get the chutes pulled to waste.

Okay, this is a blind-end drift, then, into that gravel bed saturated with mostly nitrogen. In the very end of the drift was one of those high-priority crews that you were supposed to keep in there working, and I'd go in there with my carbide lamp to check on them.

The Danger of Bad Air

Reed: Incidentally, we need to discuss the reason the bosses carried a carbide lamp, whereas the miners all had electric cap lamps with a battery on their belt. Until just before I got to Chile, all the shift bosses used an electric lamp. A man named Bob Haldeman was just one contract ahead of me; he was just finishing his first three years when I got there. He later became general manager, and he's still in Chile. He and a Chilean *capataz* went to inspect a raise that went up into an old area.

They drilled the raises blind there. They were inclined just above the angle of repose, maybe 50 degrees with the horizontal, so that the rock would fall out. There were no ladders, but there was a two-inch manila rope hanging in there on the floor. You went up hand over hand. You walked up the bottom of the raise holding on to the rope, carrying your drill, your dynamite, and whatever. When you got to the top of an active raise, you had a miner there; perhaps you were going up there to check him out. He was going to drill another five feet ahead. Every time he broke five feet, the next day he would drill two holes in the floor close to the face, and he'd lay a two-by-ten plank across those. That's what he put his stoper on to drill the holes for the next round, and that is where the rope was tied. Every day he'd move the rope up four or five feet, and it hung all the way down to the chute in the drift. When you were making your rounds, you came walking along the drift, and this guy was probably already up there drilling, making a lot of racket. There was a pipe going up the raise with air and water--

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Reed: He's drilling, and he can't hear you, and you're not about to start climbing that rope in case he knocks a rock down or something that's going to get you; there's no place to dodge. So you stand there and beat on the pipe with a wrench or a rock or something until he hears you and shuts off the drill. Then you holler up the chute, "Nothing down"--"*Guarde abajo.*" He says, "*Sube no mas*, Mister," and he sits tight and doesn't do anything; he knows you're coming up. If he's your friend, he doesn't drop anything! [laughs] You go up to see him, and you line him up and make sure he's doing all right. Then you go back down, and when you get out

the bottom you holler up to him, "*Sigue no mas*," and he goes on with his drilling.

So Haldeman and this *cabo* are going up a raise that had been finished and lain idle for some little time, to check it out before they abandoned it or whatever was next. Haldeman is going up the rope ahead of the Chilean, and they both have electric cap lamps. What they don't know is that the top of that raise is full of this oxygen-deficient air, and he climbs right into it. It doesn't smell or anything else; it just doesn't support life. So he passes out. You get no warning about this, and it's very stratified; it's unbelievably sharp. The minute his head goes into the damned stuff he passes out cold and starts tumbling down the raise. Fortunately the *cabo* is close behind him and hangs onto the rope with one hand and grabs Haldeman's body with his other arm and stops him tumbling. Haldeman came out of it with a broken collarbone. The Chilean held on, but it wrenched his shoulder so badly that it pinched a nerve, and that arm forever after was kind of inactive. I remember him well; he was still a head *cabo* there when I knew him, and his arm just hung kind of loosely.

As a result of that accident, a new rule was that bosses were not allowed to carry an electric lamp at all. They carried only a big carbide lamp. It had a bail to carry it by, like a bucket, but in addition, in the middle of the bail there was a hook like a question mark nearly a foot long. When you were writing your notes you had to have light, so you hooked that on your shoulder, and the big lamp hung on your chest and illuminated your notes.

Swent: That lamp would dim if there wasn't oxygen?

Reed: Well, not exactly. First the flame stands off the burner and gets long, yellow, and smoky; then it goes out. Yes, that was it; the lamp was your safety guide. *Capataces* were not allowed to use electric lamps, either; all bosses had to carry a carbide light. The theory was that at least once a shift, in whatever working place, there was going to be a boss go in there, and he'd get an automatic warning. If there was any question he was supposed to check. You'd raise the light up, and if you got in where the air was bad, it hung close to the ceiling. The specific gravity of nitrogen is about .98--not much different from 1, which is the normal air mixture, but enough that if it's quiescent it stratifies. It's unbelievable. People think gases are just naturally going to mix, but even though there's a very little difference in the specific gravity of the two gases, they will stay stratified if it's quiet. Very often you'd walk into a drift that was timbered with twelve-by-twelve sets, and between the sets the roof was up there about a foot or a foot and a half higher than the bottom of the caps. Those spaces would be pockets of this gas. If you walked in, you'd be hunched over and you were in good air, but if you held your lamp up in that space right over your head, it

would go out. It was that sharp. In fact, if you stuck your head up there, you'd go out, just like Haldeman did.

It was routine that you checked, and especially when you went into dead ends. On this particular occasion of the timbering on night shift--I was on swing shift, and this high priority crew was in drift Eight Left in a dead end. We were trying to keep the timber up, but every time I'd go in there at night I'd find bad air. I couldn't ventilate it in there--there was no way to ventilate it--and I'd have to take the crew out and maybe rig an air hose to blow and stir things up. This often happened on graveyard shift, and there was no time to get them back in there. So at the end of the shift I'd write in the foreman's book my message to the oncoming foreman, "I had to take the crew out of Eight Left because there was *soroche*; that's what they called bad air. He'd go out there the next day, and he wouldn't find any bad air; the air would be good on day shift. He'd give me hell in the book, say I was imagining things and shouldn't be taking that priority crew out.

This happened repeatedly, and I'm not sure if I ever tumbled to the explanation while I was there, but I know what it is now. At night, outside air is heavier, denser, colder. In effect, it's progressing down into this great gravel pile and squeezing the nitrogen out into the workings below. It's like a big sponge. At night, when the barometric pressure changes, it's still the same in the mine but it's heavier outside, so it's squeezing nitrogen out of the caved ground. It doesn't take very much. In the daytime there was no problem; in the nighttime there was. This was going back and forth in the notebook in a rather pungent way. [laughter]

It was unbelievable how sharp that stratification could be. I remember coming to Berkeley, when I started lecturing my students, and I had a lot to say about the mine gases. I've had students come back to me--one in particular, and it saved his bacon a time or two. He remembered about bad air and used a candle or whatever--anything that burns. A candle goes out at about 16 percent oxygen, but a carbide light is a more intense flame. If you ease into this stuff, it will keep burning down to about 12 percent. It gives a warning, though. The normal flame is white and smokeless, straight out, but if you start getting into bad air with low oxygen, the flame begins to go yellow and gets longer and also tails up at the end with a curl, and smoke begins to come off the curl. It could get up to three inches long instead of only about an inch and a half. So if you raise the lamp slowly, it gives you good warning. But if you just go right up, it'll pop out. So it's quite a clue. It'll continue to burn to about 12 percent, but a man gets drowsy below 16 percent and passes out at 12 percent. So if you totally trusted the carbide light it would still be going when you were gone.

The saving grace about this kind of bad air is that you'll fall out of it. If it's at the top of a drift or in a raise, you'll pass out but gravity will take over, and if the fall doesn't kill you, you'll end up in fresh air and you'll revive. In fact, I remember distinctly one time when I had a timberman with me and we went up in the undercut level. We had broken into an old abandoned raise which went up into broken ground and might very likely be a place full of bad air. I wanted nobody to be fooling around climbing up that raise, so I took this guy up there and wanted him to put a *topado*, a bulkhead, in the mouth of that raise. We were both standing on the muck pile, which was at a 45-degree slope at the bottom of this raise. I was pointing my carbide lamp up at it, telling him, "Now, you do this." He was standing on the muck pile, but one step higher than me, and he had an electric lamp on his hat. His shoulder was against my shoulder, he was that close to me, but his head was just about one head higher than mine. I was busy telling him to do this, and all of a sudden I noticed he was pushing me down the muck pile with his shoulder. I looked around, and he was passing out. His head was in bad air that close to mine. He was passing out, and I was unaffected.

I turned around and just caught him by the shoulders and eased him down the muck pile and sat him against the wall. By the time I got him sitting down, we were both down about four or five feet lower, and he came right around. But it was that sharp. You could put your light up there, and it would do its sequence of changes within three or four inches. It's a good thing to know.

The other common gas in old mines--not so common, but it happens and you wouldn't know about it--is carbon dioxide. It's heavy, in contrast to nitrogen, and it lies on the floor like a puddle of water. The hazard there is that you might go into an old abandoned mine to check or explore, and if you walked into that gas carrying a carbide light on your hat, it's not going to warn you. You're wading in maybe knee-deep carbon dioxide, and you have no way of knowing that unless you have sense enough to check with your flame at the floor. But when you walk in a long tunnel, you may walk right through a pool of gas and not know it. You get to the other end and start out, and you've stirred it up behind you. Coming out, if you should get a snoot full of that carbon dioxide--and it puts you out the same way--you'll fall down, of course. And where are you? You're lying in maybe a foot. It's like drowning in a foot of water; you would be lying in a foot of carbon dioxide, and you'd be dead, that's all. So in effect it's more treacherous than the oxygen-deficient nitrogen type air. Neither one is flammable, neither one is toxic; they just starve you to death, that's all. But it's very effective and gives you no warning; there's no smell or anything like that. I guess over a long time, if you had just a little low oxygen, you'd get a headache. But the situations I'm talking about, it isn't that; it's all or nothing. And that's sudden.

That mine was particularly interesting that way, and I've remembered it and taught my students as much as I could about it.

IV THE TENIENTE MINE FIRE, 19 JUNE 1945

Reed: What shall we go at now? We've got the hierarchy in the mine pretty well covered. Shall we talk about the fire at this point?

Swent: Yes, I think so. We don't have any dates yet.

Reed: The fire was on the 19th of June in 1945. I went there in March of 1944, so this was just over a year after I got there. Incidentally, I told you yesterday about the man who had gone to Deep Springs. He had developed a superstition in his life which he expounded upon considerably in his memoirs. The number thirteen was very big in his life; he was born on the 13th, and a lot of things happened to him on the 13th, and he lists them all. I've got the same superstition about my birthday, the 18th, because this fire happened on the day after my birthday. My dad was born on the 18th of April; Paul Revere's ride, which I can quote parts of, was on the 18th of April, "and hardly a man is now alive who remembers that famous day and year," and so forth.

It's funny, as I go along, that eighteens pop up. I can't remember them all now, but I'm beginning to get a fixation on eighteen. In fact, I'm beginning to think I'll always stay in bed on the day after my birthday, because bad things have happened on the 19th.

It is interesting to speculate as to why this terrible disaster in Chile is so little known in the mining fraternity. It seems likely that it was simply overshadowed by the war news of the time. The war in Europe ended May 7, 1945, and the world's attention was switching to the final struggle with Japan. The regular issues of Time Magazine in the U.S. didn't even mention the mine fire of June 19, 1945, in Chile. Only the airmal editions in South America carried a brief notice, which was so full of mistakes and exaggerations that it may well have been written in a Santiago hotel lounge! [see illustration]

No Positive Ventilation Control

Reed: The worst part about the fire at Braden was that there was no positive control of the ventilation in that mine. It was all natural ventilation. Indeed, there had never been a fan in the mine until sometime in the thirties. I have a Bureau of Mines paper written in 1932, and they're bragging on how good the ventilation is with natural ventilation. I won't argue the fact that there was a lot of air motion, we'll say, but the fact was that it wasn't uniform; there were places where there was no ventilation. Secondly, there was no control of it nor knowledge of where it went. Obviously, nobody had really thoroughly monitored the thing; the damned place had just grown like Topsy--this huge labyrinth of workings in the side of a mountain, like a great complex chimney.

The air would go in at the bottom and up through all these myriad connecting raises and levels and finally find its way out at the top. Then there were different places at different levels that broke out to the surface, and some of those might be outcast, and some might be incast that would be drawing more air in. The old Fortuna Mine workings that I mentioned, and which I'll come to in the mine discussion, were old workings way around at the end of the crescent-shaped ore body. In fact, that had been the original mine, way back, and had long been abandoned. But some of those workings were connected in a very remote way at the back of the modern mine. Unbeknownst to the management, there was fresh air coming in those openings and joining in with the air in the mine.

Actually, I believe that most of the men who died could have gone right around and just sat down where that fresh air was for twenty-four hours, and they would have been all right. But nobody knew that, and the men didn't get those instructions. Yet it was there; there was a ready-made natural refuge available for those 350 men who died, in easy walking distance, ahead of the smoke. But they didn't know it, and they were sent down the ladders into the smoke instead.

That's my biggest complaint, the fact that the management of that mine had never focused primary attention on good ventilation and the positive control of it.

Swent: Was it customary at that time to be so aware of ventilation?

From Chilean airmail edition only.

Nothing mentioned in U.S. editions !

LATIN AMERICA

BRAZIL

Unanimous

Twenty rugged Brazilian flyers, veterans of the Allied campaign in Italy, sat in a conference room in Washington's Pentagon Building.

Asked a reporter: "Are you going to fight Japan now?"

"Well," answered Lieut. Alberto Martins Torres, "90% of us would love to go."

"What about the other 10%?"

"Oh," said Torres, "they were killed in Italy."*

Help from Old Father

The little Army mail plane squealed to a stop on Rio's airport. Out stepped a half-naked Indian. He was Chief Inai Cachirêré of Matto Grosso's Javaes Indians. In broken Portuguese he demanded an audience with General Candido Rondon, 80, begetter of Brazil's enlightened Indian policy. Said full-blooded Chief Cachirêré to part-Indian General Rondon: "Old Father, I have come here only to tell you that a white man bought 2,986 kilograms of quartz crystal from the Javaes Indians and did not pay for it. The man is Lauro Coelo and he lives at Rua Machado de Assis, No. 45."

This was not the first time that Chief Cachirêré had called on Old Father for help. Years before, a planeload of prospectors had landed on a wilderness airstrip near the chief's village. With necklaces they had lured his pretty daughter into their plane, flown her away. The Chief had set out on foot in search of his kidnapped daughter. He grew ill. His breech-cloth became ragged. Months later, in the distant State of Paraiba, he had found the princess. Rondon, advised of the reunion, had Chief and princess flown back to the grateful tribe.

In Rio, last week, Indian Service officials had tricked out Chief Cachirêré in white man's clothes. But he was unhappy. He considered clothes unhealthy, Rio's purified water unsafe for drinking. In short-off Goiaz, federal police were tracking down the supposed quartz swindler. If white man had wronged red man in Brazil, justice would be done.

ARGENTINA

Political Hooky

All six of Argentina's national universities, usually swarming with 50,000 students, were deserted for 24 hours last week. Called out by the Argentine University Federation, virtually all the students stayed away from their classes as a demonstration against the militarist Government of Juan Perón. Argentine students, to whom politics are usually more important than Plato, have often fought each other like cats & dogs. But this time, even extreme nationalist students joined the moderates and leftists against the Government. Police offered protection for scab students, but few accepted. Those who did found the classrooms empty. Nearly all the professors had joined the strike.

* The Brazilian Air Force's *Avestruz* (ostrich) squadron in Italy comprised 50 aviators; nine were killed. Total Brazilian land and air forces in Italy: 22,550. Casualties: 1,028.

MEXICO

Scientific Diet

Diego María Concepción Juan Nepomuceno Estanislao de la Rivera y Barrientos Acosta y Rodríguez, 58, better known as Painter Diego Rivera, glorified revolution in his murals. Now he turns out rousing nudes for night-club walls, and full-length appreciations of Mexican society beauties. Through *Excelsior's* columnist Tibon, Rivera recently revealed an earlier devotion to women which was even more consuming.

As a youth in Paris, claimed Rivera, who loves a tall tale and knows how to tell one, he ate women. His motive was scientific: to prove that the human species thrives best on the flesh of its own kind. Male meat was good. (Rivera's present ambition, he said, is to taste a rump steak from Hermann Göring.) But female meat was better.

Women's brains, said Rivera, should not be derided. Pickled, they are delicious. And there was nothing more toothsome than a breaded chop cut from a charming young woman.

CHILE

Fuego!

In the world's biggest subterranean copper mine (El Teniente), in the Andes, 4,000 grimy Chilean miners blasted and drilled. Working three shifts a day, they were digging out for the copper-consuming Allies—and the Braden Copper Co.*—15,000 tons of copper ore a month. Suddenly a single spark, fanned from a forge in the mine's car-repair shop, landed among some oil and paints. Through the mine went the frantic cry of *"Fuego!"* (fire!). The flames, blown into the miles of tunnels by the mine's efficient ventilating system, raced almost as fast as the cry. In half an hour, a volcano of fire, so brilliant that it lit up the towering peaks of the Cordillera, gushed from the mouth of the mine.

Through the flaming shafts, a U.S. engineer led 400 miners to safety. But hundreds of others choked and burned to death before any help could reach them. From the mine town, *Ciudad de los Mil Grados* (City of the Thousand Steps) rushed the miners' anxious families. Anxiously, they waited for days to identify the bodies which rescue squads continued to bring out of the fire-blackened tunnels of the mine. Last week, Chilean officials had counted 393 dead, 215 seriously injured. The City of the Thousand Steps had become the City of a Thousand Mourners.

* Once owned by Colonel William Braden, father of U.S. Ambassador to Argentina Spruille Braden.

Life

DIEGO RIVERA
Anthropophagous? Women too?

Reed: It had long since been discovered in other places. My father had told me about a bad fire in the Hollinger Mine in Timmins that happened in about 1928, when I was five years old. The Granite Mountain shaft fire in Butte, Montana, killed over a hundred men and was written up in the Bureau of Mines Bulletin 188, 1922: "Lessons from Granite Mountain Shaft Fire." They had learned these lessons, you know, but nobody at Braden had ever read any of that, apparently; nobody had ever studied it.

There was a publication in 1931 by McElroy of the U.S. Bureau of Mines [USBM] which is especially pertinent to the Braden Mine.

Swent: That's well before.

Reed: Yes. It's "Mine Ventilation in the Coeur d'Alene Mining District," USBM Information Circular 6382. The mines up there are typically the same physical layout as Braden. They are a bunch of adits driven into the side of the mountain and connected vertically, so they make a natural chimney. In this paper, McElroy goes into a long dissertation about the difficulty of ventilation control, and how you mustn't take it for granted and so forth. That would have been a textbook example that they should have been reading and been aware of, because they had the same thing at Braden only more so--even bigger.

Then here's another paper, Bureau of Mines circular 6565, 1932, by Webb and Skinner. They were two engineers of Braden Copper. Mr. Skinner was still there when I was there; he was the chief engineer outside--not in the mine, but in the mine engineering office that did all the calculating and so forth. So I knew him. Webb had been, I think, a mine superintendent previously. But here they are in 1932, bragging in this paper about the good ventilation they had, which was all natural. In 1932 there were no fans. By the time I got there in 1944, I think there were a few fans.

I have a letter[1] I wrote to Professor Weeks, dated September 15, 1944, and I tell of a man in Skinner's engineering office who was assigned to install two big new fans and get them working. In the first place, he had never studied any ventilation at all; he didn't have a textbook or a reference book on ventilation, and he didn't have the performance curves of the fans, which I could have helped him with, as far as that's concerned.

It happens that at the end of my three-months *practicante* period the last thing I was doing was touring around the lower

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[1]see appendix.

control levels with the man in charge of that section. The ventilation there was almost too great, and it was cold. I had not yet learned to wear enough long underwear; I had been up where I was working hard and keeping warm. I got a tremendous case of bronchitis and spent three weeks in the hospital. They thought they saw spots on my lungs, so they assigned me for another three weeks to work in the engineering office outside. So I was working in that office; I don't remember what I was doing. I loaned my ventilation class notes to this man who was in charge of the fan business, because that was the best reference he could find, and I happened to have them with me. I didn't have my mine ventilation book, apparently, but I had my notes, and I loaned him those. That can show you where they stood on ventilation in 1944.

I might add on top of this that through the years, with their disregard of ventilation, a thousand men every day on day shift and somewhat less than that on night shift were all breathing a lot of dusty air, especially the ones in the production areas. This is andesite; it's got quartz in it. They were creating a huge backlog of people with silicosis. It only started to come to light, I guess, only in the late thirties. It first became some kind of a compensation thing, with a law to protect the health of the workers and so forth.

Suddenly the company was confronted by all these people who had advanced silicosis, and they had to pay them; they were responsible for them. First they had to get them out of the mine and maybe find work outside for them or put them on some kind of a pension system. So suddenly the lack of ventilation was beginning to hit them in the pocketbook, and I think that was the reason for these two fans. And they'd been doing a lot of dry drilling, which is the worst thing, and all these things that had been going on for twenty or thirty years were coming to a head. Of course, silicosis doesn't get you in a year; it gets you in ten or fifteen years. So there were lots and lots of people, including the mine superintendent and other gringos, who had been there for thirty years; they were coming down with silicosis.

My point is that if anybody had been doing any reading, as they should have been--somebody should have been responsible for ventilation. There were printed materials available. On mine fires, there was lots in the publications about establishing refuges in the mine--a sealed room with a compressed air supply, plus water and food if indicated, so that if men were way back in a remote area in a mine and couldn't get out the way they normally would because they were cut off by smoke, they could retreat and go in that room, shut the door tight, crack the air, and be safe for days if necessary.

In particular, up in Canada after the fire in the Hollinger Mine, they not only put in these refuges, but in order to make the men familiar with them, they also used them as lunchrooms in normal operations. The men would get used to going in there, and if they ever had to, it would be a natural thing and not a traumatic experience to go in and shut the door. But there was nothing like that in our mine, and yet we had at least two natural refuge places. One was my whole level, B North North, and the other one was at the foot of that raise going to Fortuna at the back of the mine. But nobody knew it; even the management didn't think of sending men out through Fortuna, or from B North out through B North North instead of down the raises. The latter alone cost 156 lives.

Swent: Did you have fire drills?

Reed: No, and no exits were marked, no emergency exits--nothing like that. You went in that main hanging wall drift from the shaft, and you came out the same way, day after day. Nothing was ever said about where to go in the case of a problem. They just didn't talk about a fire. I did think of all that wood on the production levels--if a fire ever started it would be hell to pay--but I don't think even that was discussed. Of course, that's not what caught fire anyhow, in this case.

Fire in the Underground Repair Shop

Reed: It was the smoke from a small fire, and the gases. What actually caught fire was a workshop way out at the Teniente One portal. They built the workshop in the portal because this was up at between eight and nine thousand feet. There was twenty feet of snow there in the wintertime, so there was no place to build a shop outside. If you had, it would have been carried away by a snowslide or something else. So it was perfectly natural to build it just inside the three portals. They opened up two or three little rooms, and built wooden bulkheads--that was a big mistake in these big portals--and the shop was just inside. It was good solid rock. They didn't need timbering to support the rock, but they needed timbers to hold up the overhead crane rails and things like that, because they used chain block hoists to repair locomotives there. So there was a goodly supply of timber right in the shop, but then there was a long way--hundreds of feet--of bare rock drift into the main hoisting shafts, and then a lot more, about a half a mile, beyond that to the working levels where all the men were. Out in this shop area there were just three men.

One of these portals with the bulkhead in it also had a coal-fired forge in it, and a stovepipe came up from that to get rid of the smoke and went through the wooden bulkhead and outside, like a stovepipe on a wood stove. What happened, apparently, was that the men got in there; they were only on day shift, so they got in there early in the morning at about seven o'clock. It was cold, of course, because right outside the bulkhead was snow; it was wintertime. The first thing they did was build a fire in the forge. They worked with oil and grease on the locomotives in this shop, so they probably put a five-gallon steel bucket of some kind of oil they were going to use, which would be thick just like molasses in the cold, up on the edge of the forge. They got it all going to warm up, and then they went around into the other room to have their cup of coffee or tea and sit by the electric stove to warm up.

You know how a forge usually has a crank and a blower--an old-fashioned forge that blows air to make the coke and the coal burn? Well, there they used a compressed air line, which blows constantly and is a lot more intense. What we think happened was that that made a blow torch and blew right on that bucket, and maybe even burned through the bucket, because it would be extremely hot, or the bucket tipped over--whatever.

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Reed: Whatever precisely happened--that five-gallon bucket of oil in the forge flared up, exploded, or did something. Of course, right there was the wooden bulkhead, so it was taken. By the time anybody knew anything was wrong--one of those guys probably stuck his head around there and raised a wild yell--it was already, I think, out of control. We don't know exactly what they did. They probably tried to do something about putting it out, but I suspect it was already beyond them.

But it certainly wasn't more than five minutes when they phoned the general mine office, which was up on C level, about three hundred feet above. It was on the surface and at the head of one of the two main shafts. That was where the general mine foreman had his office and where all the brains gathered. When the whole crew of gringos and bosses came in the mine in the morning, we got off down on Teniente 5 level at the bottom of this roughly fifteen hundred feet of mine workings, and we went to one of two shafts. There were two main hoisting shafts, and one of them went up only to B level; that was Shaft 1. A little ways away there was Shaft A, and it went clear up to C level, where it broke to the surface. There was a little town up there; some of the men lived up there in boardinghouses. And the general mine office was up there.

The way it worked was that when you got off the train in the morning, the superintendent and his assistant, the general mine foreman and his assistant, and all the mine foremen--which would be basically the three production level foremen and maybe the retram foreman--went up to C level in Shaft A, and they all had a meeting of the hierarchy up there in that general mine office. Meanwhile, all the rest of us lower echelon bosses went straight to our production levels; we went up Shaft One and walked back a quarter or half a mile in the hanging wall drift to our production levels and started our day's work.

When the mine foremen finished their short meeting on C level, they would come down a small, intermediate Shaft Two and go to their own level offices. These details are all kind of important because of the timing. Meanwhile, the men in the shop probably were there an hour earlier. They came in with the *gente* in the main workmen's train half an hour before our train, and they were already waiting for us when we got to the different levels. So these fellows were out in that shop, and as soon as the fire got away from them, they phoned the general mine office up at Teniente C. They told the general mine foreman that they had a fire and couldn't take care of it. I don't know how complete a report they gave; they certainly advised that there was a fire out of control on Teniente 1.

There were three men, and two of them ran down the drift to the shaft station, which was several hundred yards. One maybe stayed there to fight the fire, because he was the only man who was burned in the whole thing, and his body was found just outside the shop area after the whole thing was over. Of course, he was a cinder because he had been right in the mouth of it. The two men ran down to the shaft; they were going to try to get out. Again, that was their way out of their workplace--back down the shaft, not out onto the mountain. There was a door, but they didn't think about abandoning ship and going out through the door, and neither did the poor devil who burned.

The Reaction of the Supervisors to the Fire Alarm

Reed: I only learned some of these details when I started talking in January 1989 with one of the ex-mine foremen who lives in Florida now. His name is Russell Fitch. What happened was that the four highest-echelon people, the top brains of the mine, were all up there together when the fire report came. Everybody else was down on their level or on their way there. The top three men, instead

of sending the alarm out to all the workers at that point that there was a fire and to evacuate, decided they better go down and see how serious the fire was--before they advised anyone. So they left the junior man up in that office, and the three top people go out and get on the cage to go down to the level of the fire, and they are going to walk out to see how serious it is.

Two of these men had been around that mine for thirty years and had silicosis. They were in bad shape to start with, as far as lungs were concerned. One was a younger man, only recently in the mine, who moved down from Kennecott up in the States--one of the few cases where they did what I've said they should have done all along, and which Anaconda did routinely. His name was Decker.

Anyway, these three top men get on the cage. The hoist room is right there on C level, broken to the surface. They ring the cage down to Teniente 1. They run into the thickest, blackest smoke before they even get to the level, and they start coughing and wheezing. By the time the cage stops at the level, they know they can't even get off. I mean, they're about to pass out themselves, coughing and snorting. They find these two shop men taking refuge from the fire, sort of half passed out on the level platform. There's a screen gate that has to swing open to get off the cage. They want to rescue these guys, but they're against the gate, and it won't swing open. They're fighting in this thick smoke, and choking and coughing and snorting, but they manage to drag those two fellows in onto the cage with them and immediately ring it down to Teniente 5, the bottom of the mine. As soon as they step off down there--God knows how long all this took, but at least ten or fifteen minutes--then the general mine foreman steps to the telephone and calls the three production levels with the fire alarm and instructions on what to do. He could only call one level at a time, and one might presume he would call the most hazardous place first, which would be Teniente 1 North, followed by B North-B South, and then B North North.

Mr. Fitch, the mine foreman for B North North, was back down on our level in the office. Every morning when he got to the office he had a tonnage report that he was supposed to call and talk about to the general mine foreman up on C level, who he had just left, and report the day's production--the twenty-four-hour previous production, I suppose. He was in the midst of doing that when Pete Casaroto, the general mine foreman, said, "Just a minute. I've got another phone call. I'll get back to you," and he cut him off. That was the fire alarm getting up to C level, but he didn't tell Fitch that; he just said, "I'll call back." Then he ran out and jumped on the cage.

A little later, when he didn't get a call back, Fitch called the secretary, an old hand who was up there--the office manager, if you will. He said, "Is Pete there? I was giving him my report."

The man said, "No, there's some emergency"--he didn't say "fire" even then--"and they ran out. He'll get back to you." The number four man, the assistant general mine foreman, was still in the office with knowledge of the fire and didn't advise Fitch on this call!

Finally, from down on Teniente 5 in the shaft station, Fitch, on BNN, gets a call from Mr. Casaroto. "There's a fire in the car repair shop at the portal of Teniente 1. You fellows have your own exit with fresh air coming in. Take all the men out the Crosscut 32 portal."

When he called B North-B South production sections, farther in on B level, I always thought he told the fellows there to check the hanging wall drift for smoke and to exit via B North North if it was clear. However, Gordy Lee, the mine foreman for B North-B South, told me in 1989 that he did not receive that option. He was simply told to take his men down the ore pass 9 and 11 auxiliary ladderways near his office, join the men from Teniente 1 level, and continue down the ladders to safety below the level of the fire.[1] All the men from BN-BS could have walked about 400 meters down the HW drift to BNN and had a safe, easy exit. Instead, 156 of them died on the ladders below Teniente 1.

Swent: So you took your people out the XC-32 portal?

Reed: Yes, all out there, to sit on the mountainside. The three top supervisors were apparently so convinced that all the smoke would come in on Teniente 1 and go up, and wouldn't contaminate anything below the level of the fire, that no alternative exit routes were considered.

So these fellows on BN-BS got direct instructions to go down the raises, not to walk out to BNN. As I say in the paper, I know this HW drift on B level was clear for another hour, because I was out there personally walking up and down it. Also, Fitch and his assistant, Haldeman, after BNN was being evacuated, walked to BN-BS office and found everyone gone. Then they walked out to Shaft One station about the same time I checked the HW drift, but we didn't see each other. They didn't realize anything was serious until they saw rats dying out in Shaft One station. As soon as they saw those rats dying, they knew they had a real problem, and they just

[1]See appendix, Figures 1, 2, and 3.

went out the nearby portal and climbed up to the Teniente C office above.

Swent: Outside?

Reed: Yes, you could climb over the mountain to Teniente C if you knew where you were going.

The mine foreman in the Teniente 1 North office was presumably the first to receive a warning call from Mr. Casaroto, and he was instructed to evacuate his level and send everyone down the ladderways of ore passes 5 and 7, just off the HW drift and 100-200 yards from his office. These auxiliary manways were out where the men had no normal occasion to be familiar with them, and no such emergency alternate exits had ever been marked as such anywhere in the mine. There had never been a fire drill or bosses meeting to discuss emergency mine evacuation.

The Injection of Carbon Monoxide

Reed: The three top supervisors had just stepped off the cage on Teniente 5 and made those three warning phone calls, when there was a hell of an explosion. Now, if that explosion had caught them in the cage up at the Teniente 1 level station, that would have wiped out the brains of the whole operation right then, before any warning had been given. See what I mean? They had no business going to find out how serious the fire was before they gave a warning. At least they could have warned everyone and then gone to find out how serious it was. Or sent one of them to find out, but all three of them went down, without sounding the alarm.

There was a strong natural ventilation tendency inwards at Teniente 1 portal, but because the bulkheads were there, actual airflow was limited to leakage. In effect, there was a big differential pressure from outside to inside against those bulkheads. Meanwhile, everything in there--the five gallons of oil and God knows how much other oil; there were two or three barrels of oil in there, grease and oil for locomotive repairs, and greasy locomotives, working pits, hoists, and tar paper; they used a lot of tar paper to keep the natural groundwater drip off equipment--all that would generate real thick, oily smoke, and with incomplete combustion because there wasn't enough oxygen for it.

This explosive mixture was filling up the space and moving in towards the shaft, because the bulkheads would leak some. [referring to figure 3] This is the level of the fire. Here is the

fire, in that little shop. Those are the shafts, shaft 1 and shaft A, and they have big shaft stations--big volume areas. All of this area was full of what turned out to be explosive smoke. You've built a fire in a wood stove and know that sometimes it smolders and doesn't get going. You go back to see how it's doing, and when you jerk open the door it explodes, right up the flue, even; you can see the sparks fly out the top. Well, that was the condition of this whole big area, including about a thousand meters of large drifts and two shafts.

At that point, let's say, one of those bulkheads finally is weakened by the fire, and the pressure pushes it in. Now you've got a hole there maybe ten feet square. It's just like opening the draft on a stove. All that oxygen comes in, and the whole damned thing explodes; this whole area explodes. That's what really did the damage. It did several things. There were a few big steel ventilation doors in here, but thin, flimsy steel, you might say. It turned them inside out. It just blew them, and they were standing there, wide open. It created a hellacious volume--God knows how much--of carbon monoxide, because it was still incomplete combustion. It did explode, but it was really incomplete combustion, so it was carbon monoxide, not carbon dioxide, and very high concentration--probably 1 or 2 percent, at which level carbon monoxide is about like cyanide gas; it only takes about one good breath and you're dead. Not just a headache or passed out, but you're dead.

So first off it created a huge volume of this, and then it was trying to go somewhere. So it injected it into all the workings. Not just a flow of air, but an injection which went <u>downwards</u> as well as <u>in</u> and <u>up</u>; it was every which direction. Imagine if those three supervisors had been in the cage on that level in the midst of that; that would have been the end of them right there. They just missed it by a few minutes, and thus the whole mine organization just missed getting decapitated by that same time and without having received the fire warning.

I'm sure the bulkheads didn't all go at once. I don't know this, but I felt the explosion myself and was getting the word from my foreman, who had been in the BNN office when they got the word. Haldeman and Fitch were in this BNN office. I was out already on the level, B North North, and the office was here in the hanging wall drift. This is crosscut 2, and there was a big steel door here [referring to figure 2] going out of our level into HW drift. Over here there was another connection at 25R, and there were doors there and also into the HW drift.

Swent: We're looking at figure 2 (Teniente B level). Just before this we were looking at figure 3 (Teniente 1 level).

Reed: I was out in the level, in 3 Right, walking along. In fact, I had already been out crosscut 32. One of my first duties was to walk out and check this portal in the morning. I had walked all the way out and had just come back in. I was in that 3 Right drift when I met Haldeman. When Fitch got the phone call from Pete Casaroto in Teniente 5, he sent Haldeman out to tell me to get everybody off the level. Haldeman and I met in 3 Right, and he was standing there talking to me, telling me about what was happening. Of course, he didn't know much except that there was a fire and to get out. We both felt the explosion standing there. We were three hundred feet above it and way back through some doors and a whole bunch of workings, but there was no question that we felt an explosion--not a sharp one, but a big "whumph."

That's the only explosion I felt, but I was busy taking my people out from then on for the next hour. Fitch seems to remember more than one explosion. I have no confirmation of this. However, I can visualize, thinking back to what caused the first explosion: suppose another bulkhead gave way after five minutes? That would give another gush of more fresh air. There might have been lesser secondary explosions, but not like the initial one.

Getting the Crew Out

Swent: Did you have any way of getting in touch with your men other than just going to them and yelling at them?

Reed: No. I found my *cabos* and started them going in, one guy in each direction.

Swent: But it was all just by voice--no walkie-talkies or anything like that?

Reed: That's right. There was no warning system in there. Some such things came later, after the fire, like blinking lights and a stench warning system.

Swent: You had to go physically and find them and tell them?

Reed: Right. But that was not bad, because you had quite a few helpers. You simply started somebody going in this crosscut, say, and one person would go up this drift, one up the next drift, and go on through and come out the other end, bringing everybody with you. And our air was always completely clear. It never did get smoky, so there was no alarm or panic to our group.

When I finished getting everybody sent out, then I personally went and checked. I looked down each drift and could see no lights. I was convinced that nobody was left in there. Haldeman must have gone back to the office to be with Fitch. Fitch has told me recently that the two of them then, having got me started, walked all the way over to Gordy Lee's office, the B North B South office, which is right here [referring to figure 2], to see if he was okay. And everybody was gone; they'd already gone back the other way and down these ladderways. So there wasn't a soul around. They actually delayed quite a little while, looking for all the time cards the male secretary would have had. The male secretary on each level had the responsibility for the time cards--getting them all made out and getting the foreman to sign them during the day's shift. Then the cards were handed back to the men as they went off shift. They knew the time cards would be a record of the men who were on the shift, in case anybody was looking for them. I don't know how long they spent--five minutes?--rooting around. Incidentally, they found the cards on that guy's body, somewhere below Teniente 1 level; he had them in his shirt. He was a good secretary; he took the cards with him.

They spent some little time out there, and then they walked all the way back down the HW drift and all the way back until they got to shaft 1, right near the portal. They had seen no smoke, but there they saw the rats dying, so they just went right outside. They shut a door or two that were out here [refers to figure 2]. I think there was a door right here to shut off this shaft from the hanging wall here.

Fitch remembers standing out on the dump outside this portal, and from there he could look up and see the sheet iron roofs of the office up at the head of Shaft A. This is Teniente C--this surface office layout, which is quite a little development, with shacks and sheet iron roofs. The smoke was pouring out the head frame of the shaft. The head frame on this shaft was really just a big slot in the rock. The shaft was just inside there, and the hoist room was in the rock. The roof of the whole thing was just the sheet iron laid over the slot in the rock. All that smoke went into the hoist room. And that's another thing--it drove the hoist man out. When they wanted to go down that shaft, the hoist room was already full of smoke. Ultimately they put an oxygen breathing apparatus on the hoist man so he could run the hoist. They didn't have the shaft isolated as they should have.

Fitch says he remembers looking from here [referring to figure 2], and he kind of thinks there was an explosion after he got here. He saw something come out, like the roof blowing off. The roof did get blown off this slot I'm talking about. The explosion blew all

the sheet iron off, and the smoke was pouring out. In other words, the explosion force started at Teniente 1 portal and continued clear out the top of Shaft A. That isn't so surprising, because all this volume was full of explosive smoke, and when it went, it just blew the roof off clear up there, more than five hundred feet above.

Swent: And quite a way in, also.

Reed: Yes. The volume of what exploded was huge. It wasn't just that little portal shop; it was all that drift and shafts full of smoke ready to go, too.

This B-level HW drift was clear a long time [figure 2, B level, drift between shaft 2 and BN office and tool room]. Between B North B South office and B North North office and level was just a drift of about a thousand feet. Fitch and Haldeman, at least a half an hour after the warning, walked in and out that drift, long after those on BN-BS had already gone down. They could have done the same thing, but they all went down to Teniente 1 level and went to the ladders and followed their instructions. These two guys walked out to Shaft 1 and the portal, probably before I came back in from checking my BNN level.

By this time I had finished my evacuation in here, and I went back out to this [figure 2] to check the doors. I checked the doors in crosscut 2, and I walked out to the foot of this little shaft 2, which was an internal shaft; it only went from Teniente 1 up to Teniente C. I looked up and down the HW drift, and I could see a long way. There was no smoke in there, and I didn't see any lights moving or any people. I went back through the level and went all the way around and out to drift 25 Right, where there was another connection to the HW drift. I think I remember closing the two doors there that sometimes were open. This was all about an hour after the alarm, and that entire HW drift was still clear and trafficable with safety.

Then I went out to the crosscut-32 portal. One thing that isn't in the paper I will own up to now. I sat out here with all my men at this portal for several hours. I had no communication whatsoever until about noon. I was beginning to wonder what in the heck was happening. I had no idea what was going on, and I had no further instructions. I thought I would try going back in to see if I couldn't get to a telephone and find out what was going on. I went all the way back in to crosscut 2 by my tool room--the door was just outside--

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Reed: I went in and stuck my head through that door. In the first place, I couldn't get into the tool room to a telephone. So I thought that out at the hanging wall drift, which is maybe fifty meters out, there was a time card office, and there might be a phone there. The smoke was so thick on the other side of that door that literally I held my lamp up in front of my face, and I couldn't even see the flame on it. Of course, I should not have gone through the door. I didn't have any idea how lethal that smoke might be; and it wasn't that bad, as a matter of fact, or I'd have been dead right there.

I walked all the way out that fifty yards, banging my lamp against the rail of the track to guide me. I knew there were no holes to fall in or anything like that; it was familiar to me. But in order to know where I was, I was following that rail. When I got out to the card office, the door was locked, as it should have been, and I couldn't get at the phone. So I turned around and went back. I didn't try to go up to our own office, probably because I didn't have a key to it. Anyhow, I'd had enough of that smoke, and I went back.

That tells me that although this area was full of horrible smoke, it was not lethal smoke at that point, about four hours after the fire. I know now what was going on just four hundred feet below on Teniente 1. All the lethal stuff had gone through the mine, but it probably just wasn't getting up in this area very much. It certainly wasn't full of carbon monoxide, or I'd have been found right there. It just wasn't my time.

I went back out to the crosscut-32 portal, unable to reach anybody, and then I got disgusted and climbed up over the mountain like the other fellows had. By that time these fellows who had gone up to Teniente C had begun stringing fire hoses down over the outside of the mountain, and a crew of men were climbing up and down ropes--because this is a steep, rocky mountain--to start trying to put water on the fire. That's how I spent the afternoon, down there outside those Teniente 1 portals, which were all burnt out by this time, spraying water in there to cool it all down. It was like looking into the mouth of a blast furnace, with a horrendous blast of air going in, nothing but red-hot coals, and the crane rails--the big I-beams and so forth--that had been up on timber had all fallen down and were like pretzels, almost melted by the heat. Every last vestige of that fire and fumes had gone inwards. It didn't come out at all, because there was a terrific draft going in. That's what killed everybody, of course, because it just all went into the mine.

We spent the rest of the afternoon cooling that down, and late in the afternoon we walked home from there down over the mountain

and back to town. People started going in the mine, I think, aometime late that night with oxygen apparatus. I think by midnight we knew there were a lot of dead. The next day we started checking out the whole mine, and I walked around with Haldeman and Mr. Decker on some of the levels.

Finding the Casualties

Reed: It was evident, as the bodies were found, that they had died almost instantly in most cases. They'd be walking along a drift where there was just a plank to walk on between the rails, single file, and you'd find them head to toe down that plank--not piled up in heaps or anything like that--so a gush of that gas came through and just dropped them without a warning or anything--no struggling, no staggering. A lot of them would be sitting on a piece of timber against the wall with a sandwich in their hand, a mouthful of sandwich, even, and they'd be dead.

In the ladderways it was worst of all--in a raise with ladders in it. There was twenty feet of ladder, and then there was a bulkhead. The next ladder above that bulkhead was offset, so that if you fell off a ladder you could only fall twenty feet and you pile up on the bulkhead. When you're traversing this, you get to the bulkhead, if you're going down, and you walk around to the back side of the ladder, and that's the only hole in the bulkhead to go down on the next ladder. So imagine what happens if you've got a steady stream of men--solid men--on that ladder, and then they all get gassed. There will be about four or five in a heap on every bulkhead. That's what they found when they went in there to start trying to get people out. Sometimes they had to cut the bulkheads out with an axe to get through, because they couldn't get through the pile of bodies on top.

They found one man alive in that mess the next day. We always thought that he had been under such a pile of bodies that he couldn't take a deep enough breath to kill himself. But he was the only one, except for the few that I told you about who were way out somewhere and had sense enough to stay put; they survived fine, of course, because it was just one great big, very short-lived gush, I'm sure, of very high concentration carbon monoxide, and then it was gone. All those people could have just walked to the back end of Teniente 1 in crosscut 62 at the foot of the raise to the Fortuna (figures 1 and three), and that would have been a natural refuge. And, as I say, the use of refuges was known and had been written up. I really think it's a terrible example of neglected planning and education around a big mine.

Lessons To Be Learned

Swent: I notice that the title of your subsequent article, in the Mining Congress Journal in August, 1955, was "Mine Safety: Every Mine Fire or Explosion Can Be Prevented or Controlled."

Reed: I was very convinced of that when I came home, and I read all those references in our library. The Mining Department here in Hearst Mining Building had its own little library, very complete, just off the office. Also there was a U.S. Bureau of Mines experiment station in that building; they had their own library of bureau publications. So I did a lot of research there in my four years that I was here as a graduate student.

Swent: That was after the fire?

Reed: Yes, the first time I got back up here and had access to things like that. I read everything I could lay hands on about this, and I distilled it all into that paper, but without naming names or anything. In fact, I didn't have a reference list on that 1955 paper, but there is a list that I put on the end of this 1989 paper. I should add a list to the 1955 paper and enlarge the one on the 1989 paper.

There is a USBM Miners' Circular 55, which is all about mine fires and mine safety with fires. It has an extensive bibliography, and I went down that bibliography and read almost every one of the important references. All the major disasters, like the Argonaut fire, the Granite Mountain shaft fire, and quite a few coal mine fires with loss of life--the big ones--are all written up. So if anybody gets interested--for example, if a mine ventilation engineer is assigned that responsibility, he would be the logical one to read those kinds of things. But, you see, Braden never had a mine ventilation engineer; they never thought they had a problem of ventilation. They didn't even have anybody assigned to that job; they just gave it as a little side issue to this one engineer to put in a couple of fans. Yet, again in that letter to Professor Weeks, I point out that there were at least seven of us on the staff, starting with me and clear up to the general manager, who were all graduates of Berkeley, so they must all have had a pretty good indoctrination from Professor Weeks. But we were too busy doing other things. Nobody talked to us about

ventilation. Our job was production; don't bother us with details; get on with the production.[1]

I remember one situation later on involving one particularly obnoxious superior of mine who apparently never had any ventilation, or at least he didn't remember it. We had three parallel drifts open at both ends to a crosscut. The air was supposed to come in one crosscut, sweep the drifts, and go out the other crosscut. But there was very little positive ventilation pressure, and the dust and the smoke in those drifts was horrendous. Not only was it unhealthy, but we weren't getting any production. Somebody decided we ought to put a little booster fan in each one of those drifts to boost the air through there--get more flow within that drift.

A timber set is normally over six feet high and about four feet wide. But if it begins to take weight and the two posts begin to get pushed horizontally inwards, you've got to maintain passage for the ore car. So one thing you could do, and we often did it there, was to put in what they called a "traversal." In other words, you slapped in a round stull, like a little round fence post, horizontally between the two posts and wedged it. It tightens up and stays there. It's got to be above the top of the car, putting it about four feet off the floor, so when a man comes along he's got to duck every one of those traversals. You have to kind of duck walk; if every set has one for a ways, you get darned tired of ducking, and if you forget to duck, you get set on your behind because your hard hat hits it and stops you dead.

I got the orders to supervise the installation of those fans. It was just a little fan, and they put it above that traversal in this little space that may be a foot and a half square. They mounted the fans up there so they'd be above the car also, but they didn't put any bulkhead in, so the fan was just blowing like heck down the drift. Well, that isn't the way you ventilate. You've got to put a bulkhead in, and the fan takes the air from one side and boosts the pressure of it to the other side. That makes the air in the whole drift flow one way. But if you just put a fan up in there blowing without a bulkhead, you're really just stirring the air up locally; it's just running around. It makes a big noise and makes somebody think that they're ventilating, but if you go to the other end of the drift, you don't find much net change, generally speaking.

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[1]Please see letter and references in appendix. Brother George studied ventilation under Weeks seven years ahead of me, and on page 203 of <u>his</u> copy of Weeks's book, the same lines are underlined about staff meetings and hypothetical fire studies. -JR

I remonstrated. I put them in, but I said, "You know, that's not going to help anything a darned bit until we put a bulkhead in. We ought to put those fans out beyond where the car is working. Put a bulkhead in, and then put the fan in." He gave me hell. "No, that's the way we want it. Put it in." So that's the way it went in. It was just a waste of effort and horsepower, and it didn't get the job done.

Swent: There was also something about the water in the mine that changed the flow of the air. I meant to ask, too, about water there. This is terribly arid country.

Reed: The north of Chile is very arid, but Braden is in central Chile, like southern California, with similar rainfall. At that latitude it's temperate. It's like California--nice orchards and everything. Up at that mine location, the supply of water limited how much rock could be milled. In the wintertime the water tended to freeze up. We had some ponds and little streams, and we gathered all that water we could, but summertime was when you got the most water and you could mill the maximum tonnage. In the wintertime sometimes the limiting factor was the water available for the mill and to generate power.

Swent: But there was water available for wet drilling, too?

Reed: Yes. And by the time I got there, everything was wet drilling.

Regarding the fire, the water that was developed in the mine, the ground water, would come down to the first level. Then you had a water ditch, and the water ran out towards a portal. But instead of letting the water run out on each level, say to its portal, apparently all the water from above had gotten down to Teniente 1 and came out that ditch. Going back to Figure 1 in my paper, there had been an old ore pass (o.p. means ore pass), so all the water from up in here came running along. It went down an empty raise OP #1 drain and went clear to Teniente 5, the main haulage drift at the bottom where we came in on the trains from town.

Any time you have water falling down a vertical or near vertical opening, it naturally creates a down draft. The falling water, like raindrops, makes the air want to go down. That OP #1 is just inside where the fire was. Now, I think the biggest cause of gas going <u>down</u> was the explosion "injection." I used to attribute more to the water, but still the water did some; I know that, because that smoke went nearly 1,500 feet down OP #1 and was pouring out down there in Teniente 5. Upwind, out towards the portal--Teniente 5 had a portal out here, and a lot of air for the mine came in that portal (it was the same way the train came in),

and then it went up. Here were these superintendents down here, and there was the compressor station, two big shaft stations, the telephone switchboard room, and so on. The most important one was the compressor station that had to be kept going, because it was compressing fresh, clean air and supplying the whole mine through its piping system. For anybody who was holed up up there and depending on that compressed air to keep them alive during the fire, it was important that you didn't start pumping carbon monoxide through the pipelines.

So here's this doggone smoke all of a sudden starting to pour out of this water raise right outside of all this installation, and of course then it was coming right back in. Fortunately, these three bosses in the shaft station at the bottom of shaft A, who got out of the cage, got a crew immediately and got over there and got an emergency bulkhead stuck into that raise and cut that off, so at least they had fresh air to here, near Shaft A [referring to Figure 1]. But then they had doors, and all this interior portion of Teniente 5, including the shaft station, was full of smoke. Some of the men did finally get all the way down the ladders and actually got off on Teniente 5, in the densest smoke by this time, and passed out. They were lying around--they weren't dead--wheezing and snoring-like, unconscious back here on these timber piles.

Mr. Decker, a very brave man--maybe foolish, but brave--got an oxygen apparatus and all by himself. (You're never supposed to go anywhere by yourself with an oxygen apparatus; in fact, you're always supposed to have five men in a crew so that if one goes down you have four to carry him). He went back here in that smoke, inside the door. He was expecting all these people to come pouring down the ladders here, but only fifteen or twenty ever got there. Finally he heard the noises, and he found out what was going on. He couldn't carry them out himself, but he did find the air line--a big main air line right overhead, about a four-inch one--and popped the valve on it and got some fresh compressed air blowing in there. Those guys were saved because of that.

Then he came back out, and they kept that door shut to Shaft A station. (I'm getting involved now, and making a long story.) There was a secondary runaround between the shaft stations. The main hanging wall drift with the ore train traffic went on back to pull the rock out of the mine. But then there was another side track that went between the bottoms of those two shafts, and that's where the man train was parked. The man train came in in the morning with all the people and went back there. The man cars were like box cars; you climbed in the sides, and they had benches in both ends. The train sat there in the runaround, then, until it had to bring some people out at the end of shift.

One of the attempts at rescue in the early stages of the fire was from the mine rescue station, which was up on Teniente C. They had a crew of *cabos* who had all had training with oxygen apparatus, as we all did, and one of the first things they did, when this smoke was so horrible, was to send a team of seven, all Chileans, with a kind of safety *capataz* in charge of it. They all put on oxygen apparatus and prepared to go down to the fire level to find out what was going on. They didn't realize, maybe, at that stage that they couldn't have seen anything if they had gotten there. This was a case where in order to get the hoistman to let them down, they had to put an oxygen apparatus on the hoistman, because he couldn't stand at the hoist otherwise.

They went out and got on the cage, and they rang it down to Teniente 1. Already in the cage, even before they got there, one of these guys, a highly nervous, unpredictable type who should never have been earmarked for such a crew, started blowing his cool. One of his buddies, a good friend, was a calm individual. These apparatus were the old kind where you bit a mouthpiece, like a scuba mouthpiece. You're never supposed to talk, because you've got to take your mouthpiece out to talk, and then you get a breath of bad air. This guy was raising all kinds of hell, running around in the cage, and his buddy, trying to calm him, took <u>his</u> mouthpiece out. He said, "Calm down, Juancito." They soon found they could do nothing on Teniente 1. With things going to hell in the cage, they weren't about to get off on the level. So they rang it on down to Teniente 5 level.

Arriving on Teniente 5,they found the door shut between them and the clear air in the HW drift. The bosses and so forth were right at the bottom of this shaft. There was a guard on that door who had orders to keep the door shut. So here's a crew of seven men, one of them already causing trouble, beating on this door, trying to just step into the fresh air; just open the door long enough to get them in there. By God, that guy on the door said, through the door, "No, we've got orders that when you get down here you've got to walk around past where the man train is parked and come out Shaft 1 at the air shaft station, where the air is good." So they started that way.

The space in that drift beside the string of boxcars was only about a foot wide in front of the posts, and these guys have got big two-hour apparatus on their backs. It looks like a pack sack with a tin cover; it's bulky. They're all edging through there, and they're having a heck of a time. They're all still using the apparatus; they are still in bad air at this point. This one character is still raising all kinds of hell. He comes to the sliding side door, like a boxcar, and the first thing you know he jumps in there and starts running around inside the all-steel car,

trying to get out the other side. He won't wait to go single file and stay with the gang. His partner is still trying to calm him down. Well, fate would have it that the partner finally passes out and goes down with his apparatus on. The guy who's causing all the trouble still has his mouthpiece in.

The upshot of it was that they were having such a hard time getting themselves through that they couldn't carry anybody with them. They didn't drag him out of there, and that man died. He was just on the other side of a door, in the first place, and then only a hundred yards from safety in the runaround. In other words the only rescue crew that tried to get in almost lost themselves, and indeed did lose one.

V BRADEN AFTER THE FIRE

Stanley Jarrett, the New Superintendent of Safety

Swent: Have they learned from that fire?

Reed: Yes, I will say that. Stanley Jarrett is a world-famous name in mine safety.

Swent: I notice you dedicated your paper to him.

Reed: Yes, I admired him very much. He was in charge of the mine safety program for all of the gold mines in the Baguio area in the Philippines before the war. They had a cooperative mine rescue station that served all of the gold mines in the Baguio area, and it was supported on a cooperative basis by all of the mines. He was in charge of it. When the Japs came in, all the Americans in that whole district ended up in prison camp in Santo Tomas in Manila. Indeed, Stanley sent his wife and two little boys, who were about six and eight when it started. Stan was a very independent, go-getter type of person, and he thought he'd try to join the guerrillas or the resistance. He kicked around in the hills for a month or so with one or two buddies, and all they could do was get lost and get horribly sick with dysentery and so forth. They were hobnobbing with headhunters and I don't know who all. To save their lives, they gave themselves up to the Japs, and he ended up in the prison camp, too.

The whole family, then, spent three years in Santo Tomas. They almost starved to death and raised a garden to keep alive. Particularly the two little boys--Jean was concerned about them not getting enough protein and damaging their growth and so on. They were liberated in August of 1945. Incidentally, there was an execution order on the commandant's desk that he was supposed to

kill everybody in that camp before he abandoned it. For some reason or other, he didn't, but they found the order on his desk.

The Americans came in and liberated the camp, but the Japs were still on the other side of the river shelling them. Most of the people had taken refuge in the main buildings, but a few were outside and got hit by shellfire. Stan, being the safety man he was, was out running around in his half-starved state with a stretcher, trying to get these people in, and a piece of shell went right across the front of his thigh and took out a double handful of muscle. They got him back to the States, and he was in San Diego, helping with safety for the navy, within a couple of months.

The company had made up their mind by this time; I imagine the New York office had said, "Let's get somebody in charge of safety at Braden." So Stan and his wife--the two boys never came down there; they were put in school up here--showed up down in Chile during that fall, maybe in December or January--that soon. I remember particularly that leg of his. Sewell is all built on the side of a mountain. You don't walk anywhere; you climb steps.

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Reed: Jarrett got down there late in the fall of 1945. He was an interesting man, and I remember his leg that had been so badly dinged up. He just chuckled about all the steps and said, "This will be good enforced rehabilitation," which it was. [laughs] It was always a troublesome thing for him in some respects. He and I became great fishing buddies. After I moved out of the mine and down to Coya to work in the hydro-electric area, I had access to horses, which I used in my work. I could also use the horses on weekends to go out hunting and fishing in the hills. There was a very good trout stream that was about a two-hour ride from our camp.

Stan was a very gung-ho fisherman. On Friday afternoon he'd get on the autocar; on the railroad, instead of a train they had something like a Ford truck with a bunch of seats in it, open like a great big touring car. It held about twenty people, and ran fast on the railroad track by itself, in between trains. That's what the gringos, the gold roll employees, rode. Stan would come down and get to Coya about five in the afternoon, and I'd be waiting for him, where he jumped off the car at the railroad track crossing, with his horse all saddled and ready to go and mine with the saddle bags and all of our grub, two sleeping bags, and so forth, tied on. We'd take right off from the railroad crossing and ride through part of the camp site and off along this trail. We'd get to the

Rio Clarito--the little river--in time for a half hour's fishing maybe even before dark.

Then we'd fish all day Saturday, sleep Saturday night there again, and then we had to ride back on Sunday. We could fish in the morning, and we'd ride back to Coya. He needed recuperation time when he got back, because that leg, riding horseback, was really giving him trouble. He'd be real sore and stiff and tired by the time we got back, between the fishing and the two horseback rides. We'd get him off at my house at maybe one or two in the afternoon, and I'd get him inside where he could stretch out and get that leg up. I'd start feeding him Pisco Collins. Do you know what pisco is?

Swent: Isn't it South American brandy?

Reed: Right, it's grape brandy. Up here it would be the equivalent of grappa amongst the Italian winegrowers. It makes a real good mix. Pisco Sour is the cocktail up and down the west coast of South America--Peru and Chile. I've converted it to a longer drink. I just made up a Tom Collins, only with pisco. I'd get three or four of those into Stan and get him anesthetized by the time it was time for the car to go back up the hill. I'd drive him over there and load him onto the car, and he could have a good rest and a snooze for an hour and a half before he got home back up to Sewell. But, heck, he'd be groaning and griping about that leg when I'd put him on the car every time, but in a week or two I'd get a phone call, "Let's go fishing again." [laughter]

The other funny thing about Stan was that when they arrived--of course, they had just come down post haste by plane. All their things, any furniture and all their stuff, was coming by ship two or three months later. They had a company house assigned to them, but there was no furniture in it. Meanwhile, by this time I had gotten myself engaged, and my wife-to-be was still in the States going to school. But I had gotten a great opportunity: when a gringo left down there, he had a whole house full of furniture that he didn't want, and it wasn't worth shipping home. So he'd try to sell it. The easy thing was if he could find one person to sell the whole thing to. So I had bought, at a bargain, a whole house full of essential furniture. But I didn't have any house yet, so it was stowed in a spare room in the staff house, just stacked.

Well, here come the Jarretts, and they need some furniture, and I don't need it for six months. So they used all my household furniture for six months before I did.

Stan was a tremendous organizer, though. I guess the company had had something called a safety department before, but it was

just sort of in name only. But Stan made it become--well, he got the backing, I guess. I think his department had as much prestige almost as the operating departments in the whole property--not just in the mine, but in the whole place. He was just a marvelous organizer and safety man. He'd research things and so forth with his people, and he put out tremendous safety books; they'd have seminars for everybody, and all kinds of activities like that. The upshot was that Braden Copper Company and the mine became the safest mine in the world, going from the other extreme at the time of the fire. In fact, it especially became the showplace of all of South America. Other companies in other countries would come to visit, and then they would ask Stan to come and help them set up departments. So he often was loaned by Braden to Cerro de Pasco, or to someplace in Bolivia, the tin mines, and so forth. He went all over the continent down there helping them get equally well organized. So he really made a name for himself.

I guess you probably know that when he retired down there--I don't remember when it was, but it was during the sixties, because I was at the time at Colorado School of Mines. Knowing him so personally, and knowing that he was going to retire, I wanted to hire him to come there and teach mine safety on our staff. And, by golly, he never had any degree at all from college; he had a high school education, that's all. So academically I couldn't get to first base. Yet he became the head of the U.S. Bureau of Mines Metal Mines Safety Division for some years. Bill Wood, down at Oracle, Arizona, near San Manuel, was his second in command at the Bureau of Mines. Of course, Stan consulted all over the world--all those mines in New Guinea--up until the day he was killed, on the day after <u>his</u> birthday (I'm getting careful about birthdays, now). He was going fishing. He celebrated his birthday in Sanger, near Fresno, and the next morning he got in a Blazer with a couple of other guys. They drove way up near Crescent City all in one day. I suppose the driver was tired, and the car skidded and rolled off the road. The only one hurt was Stan. I don't think he even regained consciousness. He was badly bashed up and died. That was a sad way to go. He was eighty years old. He had a good life, but that was a rough way to go.

But he made the mine a very safe place.

Swent: I guess people were willing to learn then.

Reed: Right. They were finally receptive.

Swent: Fishing didn't do you much good either, did it?

Reed: Well, it is strange that I got sick over at that same place, but fishing had nothing to do with it; that's just where the bug got

triggered. They told me afterwards that there is an incubation period of six weeks, so I'd been carrying the bug around with me for God knows how long, and no telling where I got it--out of the milk, or whatever, or maybe somebody carrying it. We didn't have any other cases that were recognized on the property.

Swent: We should say what it is we're talking about.

Reed: Polio.

Swent: Did anybody else get polio?

Reed: Not that we knew of--not up at the mine, not in our area. There was an epidemic in Santiago, so there was lots of source for it, but how it got up the hill, I don't know. The company doctors didn't recognize or call it by name for weeks, so there could have been mild cases around there that they never even identified, and they'd still be infective.

Swent: This was in 1950.

Reed: Yes, January of 1950.

Swent: Not much was known about polio at that point.

Reed: They did know about keeping track of your feces and that sort of thing. I remember they instructed my wife to be sure that I didn't contaminate anybody else. So they knew enough to do that. I guess you'd do that with cholera or any number of different things. Of course there was no vaccine yet, but Salk came along soon after. I can remember when I got up to Berkeley, my kids were getting the first little sugar cube with the drop on it. I know it was before I left Berkeley, so it must have been in 1954 or 1955. I left here in June of 1955. My eldest boy was kindergarten age.

Swent: You mentioned a trip that you took across the country.

Reed: That was in the fall of 1948. It was my first paid vacation home from Chile, which normally you would get after a three-year contract. But during the war, that went by the board. In the meantime I got married, in 1946, so on the first trip I was bringing home a new wife and a year-old boy. We were going to pick this car up in New York and drive it across the states. I took great pains to choose the non-infective route of the hot spots of polio in September of 1948, and in January of 1950, one year later, I'm back down in Chile and get it myself.

Living in Sewell

Swent: You mentioned that you had left the mine and went to Coya.

Reed: Sewell was where the mine was. Sewell is about 7,500 feet. You go in a train from there that goes up in a shed in a tunnel a long way--about a half an hour ride--and you go in under the mine. That was then; it's not now. The mine reached up to maybe 10,000 feet, but the town of Sewell was 12,000 population, and it was right on the hog's back between two canyons--the Coya Canyon and the Teniente Canyon that the mine was on. Since the town was built entirely on that v-shaped ridge, you couldn't have a snowslide in the town because the town held all the snow right there. But the wall of the canyon opposite, on both sides of the town, was not built up and was extremely steep, and snowslides were very frequent.

Snowslides

Reed: In August of 1944, the first year I got there, there was a whole series of snowslides. One night, about seven o'clock, it had been snowing for about a week without stopping. The normal snowfall there in a year was about twenty feet, so there was God knows how much piled up on these two big steep slopes. Probably one slide triggered another, because more than one came down, and some huge slides came down. The town didn't reach right to the bottom of the canyon, but within a couple of hundred feet of it. When the snow came down the opposite side, it hit the bottom so hard that it swirled up on our side and back down into the canyon. That swirl reached into the lower edge of the town. There were three buildings like fourplexes in a row. The normal, or more usual, building in town was a big tall apartment building, four or five stories high, with a central hall and apartments off both sides of that central hall; it was a long, narrow, tall building, called a *camarote*.

This darned slide came and got all three of those fourplexes--just picked them up bodily and completely mashed them, of course--and dumped them in the canyon under forty feet of snow. It got the ends of one or two of those big *camarotes* (which sounds like a bunkhouse), and it would just completely ruin the end apartments and pack them full of snow. A snowslide is a disastrous thing. One hundred fifteen people died there, just in a flash [snaps fingers], like that. The worst part was that it was about seven o'clock in the evening, and in a lot of the families half of them

would be up at the theater, going to the show, and the other half was home. After the show they came out, and there wasn't even a home, much less a family. It took about two weeks to dig them all out; they were all packed in that snow.

I've got pictures of snow barriers built afterwards, and things like snow fences--experimenting, trying to get some purchase on that slope to hold the snow up there. I don't know how successful they were. They tried different things. They made rigid fences with great big steel beams, and they'd just get bent over. Finally they learned to put two huge pylons of steel beams, dug into the rock and set in concrete, one on each side of each little ravine. Between them it looked like a big volleyball net, but it was one-inch cable across there. That would break up the slide, but it had enough give and resiliency that it wouldn't get torn away. I guess that helped some.

Snowslides are a big problem. Other mines in Chile--the Andina mine, which is just north of Santiago, recognized the problem. This was in my time, and I went there to consult when they were making it in 1970. They mined out the mill; the mill was entirely underground, and a lot of the other facilities were underground.

Swent: To prevent this kind of--

Reed: Right, because there was no safe place to build a town or a big mill or anything like that.

Swent: This town was all company--

Reed: Sewell, yes.

Marriage

Swent: Is that were you lived?

Reed: The first three years, yes. I went there in 1944, and by early 1945 I had met my wife-to-be and was engaged. She was the daughter of the chief electrical engineer.

Swent: She came down there to visit?

Reed: No. She was born in the States, but her parents went down there when she was only a year old, so she grew up there, went to school in Sewell, and went through high school at a boarding school in

Santiago. She was going back to try and get some junior college in New Jersey, so she went up there for a year. It was during that time that the fire came along.

We were married in July 1946, and my contract would have been up in March 1947. I had already made up my mind that I had had enough of the mine. I mean, three years was all I was going to take of that, and I'd learned all of value. So I basically let it be known that I would be leaving at the end of my contract. Well, by this time I was married to the daughter of the chief electrical engineer.

Swent: What is her name?

Reed: Eileen Butler.

They were upgrading the powerhouse in Coya. It was built back in about 1920, and originally it had about six small hydroelectric turbines in it. Sometime before I got there they had started upgrading it by taking out two of these small turbines and putting in one large one to replace them. They'd gotten that done twice, and they had the last one to put in and were well into it. Len Hawes was the hydraulic engineer and construction superintendent of all that kind of thing, and he was an ex-miner, too. He had served his time in the mine and had moved down there twenty years before. He was looking for an assistant to help get this thing installed, and I guess they decided that I would do. That would keep me around and give me a change of scene and something to do. I welcomed it, because I had gotten interested in the powerhouses.

Swent: This was a hydro plant. They had enough water year-round?

Reed: Down there, yes. Well, the lack of water for milling was both up at the mine in the actual mill itself for handling the rock, but also the power, because they generated their own power for all the grinding and everything else. So in the wintertime, again, the streams went down for the powerhouses. There were two powerhouses, actually. So that's right, the limit in the wintertime was the water supply for both the milling and the power to do the milling.

Anyhow, they kind of twisted my arm. I was ready to leave in February of 1947. They said, "Well, we'll give you this job down in Coya, but you've got to stay on until August or September up in the mine until we get somebody trained to take your place." I knew that was a lot of guff, because I'd seen through the years that they just made do with what they had; there wasn't any training done. They just wheedled six months more service in the mine out of me, that's all, which was the hard part.

Swent: At least you didn't have the problem of getting a wife adjusted to life down there. She knew what it was like, and her mother and father were there.

Reed: Oh, sure, and she was totally bilingual, of course.

Swent: That would solve a lot of problems.

Reed: That's right. That part of it was much simpler.

Swent: In fact, she might have had trouble adjusting to life up here in the States.

Reed: She might have, I think, because up here we didn't have maids or anything like that. We didn't have a maid up in Sewell at all. The eldest boy was born up there just before we moved down, and after we got to Coya we had a maid who would come just during the day. Most people had a live-in maid, but this girl lived across the river in the non-company town. I think it was five dollars a month to have a maid all day. I don't think it was seven days a week; she must have had a day off somewhere along the line.

Gardening and Smelter Smoke

Reed: We were assigned a house up in Sewell. This gets me around to one of my favorite stories. In Sewell there was no soil, no vegetation at all, just bare rock, and most of it on end--very steep. So the houses were all built on steps in the side of the hill. Your house was one-story high on the uphill side and two and a half stories high on the downhill side. There might be a path there, and then you were looking at the other guy's roof out your window on one side. You were looking at a foundation on one side and a roof on the other side. There was nothing like a garden, so you were dying for something green to look at. Everybody had a little flower box on the railing of their front porch, and you could have some petunias or snapdragons.

This gets around to the smelter smoke. The smelter was at Caletones, five miles down the canyon--a very steep canyon--and quite a bit below us. Through all the wintertime the prevailing wind blew the smelter smoke across the canyon and back into the mountains; it didn't come up the canyon to Sewell. But when the winds changed in the summertime, then the smoke began to come right up the canyon and was just dense. All summer long you couldn't hardly stand to walk outside because you were getting sulfuric acid in your throat, is what it was, and you had a raw throat all the

time you were outside. The best part of working in the mine in the summer was that at least there was good air compared to that.

Early in the spring you'd get busy and plant your snapdragons, petunias, and sweet peas in your flower box, and they really went great--until the smoke came. Then everything but petunias died. This puzzled me, after I watched it for a while, and I got to thinking that it had something to do with the foliage. Petunias have kind of succulent, thick, pulpy, sticky leaves. I was thinking that we needed to find other plants of that ilk that might stand it. At the back of our house we had just a tiny little concrete plaza about ten feet square with a wall on one side with some dirt in it and another flower box on the other side. I was casting about for something useful that I could plant out there in the way of a garden (I don't know why I wanted a garden), and I came upon squash. I thought that, by golly, I would try squash, and, sure enough, they did great. Great big healthy plants, and they spilled down over the wall, trailing down. The smelter smoke didn't bother them. Boy, I was just licking my chops for Hubbard squash done in the oven.

These big, beautiful flowers came out, but I never got any little squash. I kept looking and looking for the little squash to form at the bottom of the flower. I began to analyze that problem and decided that there were no insects up there--no bees running around and doing their thing, fertilizing those lovely big flowers. I thought I would have to pinch hit, so I found a little water color brush and went out and carefully dabbled around in each flower. I thought now I would just sit back and watch the squash come, and it still didn't work. I never got any squash.

But I had one consolation. At the very end I said that I was the only mining engineer on record who had pimped for a pumpkin. [laughter]

Swent: You never did figure out why they didn't produce?

Reed: Not really, no. I still believe that they weren't being pollinated, because the plants were very healthy, and the petunias did fine. But it is peculiar. That smoke was selective in what it would kill. It didn't help things much.

Social life

Swent: What did you do for social life besides fishing? What did your wife do?

Reed: Up in Sewell there was precious little. You went to parties at each other's houses. There was a movie, where they had a fresh movie twice a week or maybe more often.

Swent: American movies?

Reed: Mostly, and they often had Spanish subtitles; or they came dubbed in Spanish with English subtitles. It was funny to see the movies a lot of times. Sometimes they were hilarious because the dubbed in parts were literal translations that had second meanings. Sometimes the audience would burst out roaring with laughter because something was questionable.

Swent: Some of those dubbings were awfully good, though, as I recall. They don't do that any more.

Reed: That was one entertainment.

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Reed: The Teniente Club was like a social club, and they had a swimming pool, big lounge rooms, and a party room.

Swent: Teniente was the name of just that one mine?

Reed: Yes, it really is the name of that mine--the Teniente mine--but it was Braden Copper Company then.

Swent: And Sewell was the town?

Reed: Yes, the *teniente* came from the fact that a lieutenant in the army supposedly discovered the deposit in the eighteenth century. The first production was in the early nineteenth century, and by about 1900 a Frenchman controlled the property. He called in a prominent American engineer, William Braden, who inspected the mine in 1903. He was the father of Spruille Braden, who later became the American ambssador to Argentina. The town of Sewell was named for Barton Sewell (from A. S. & R. [American Smelting & Refining Company]), who became the first president of the company in 1904. Kennecott took over in 1915.

The Teniente Club was the social club for the gold roll people--the dollar payroll people. They called it the gold roll, but you didn't get paid in gold; it just meant dollars. There were quite a few Chileans who were on the dollar payroll, too.

Swent: Was your pay given to you there or deposited in the States?

Reed: It was credited in the States. You got a monthly statement, which I can show you here, and they paid your taxes and all these different things--social security, and a family allowance for people with families. But if you didn't have a family, you paid into that; that's how they financed it.

Swent: It was an incentive to have a family!

Reed: I suppose so, and the more kids you had, the more you got, too. A lot of the Chileans had six or eight kids, so they'd get a pay-back. Ultimately it was deposited in my bank account up in the States.

Swent: So that's why you had to pay American taxes on it?

Reed: No, I did not have to pay taxes in America; I paid Chilean taxes. The first year you leave the States, you still pay taxes for that year in the States, and as soon as you get back--I think if you come back in November, you'd still pay another tax in the States. But after the first year, for the five years I was down there I paid no U.S. taxes and filed no return.

The Teniente Club was the place where they had parties and pool tables, a swimming pool, and a bowling alley. Right in the mine staff house we had a bowling alley and some pool tables. There were quite a few things to supposedly keep you occupied. Everybody wrote a letter at the end of their *practicante* period with suggestions--their reaction to that three months and any suggestions. One of my suggestions was that I liked to ski, and they had never done anything there to help develop recreational skiing. I said that a real simple hoist and a few facilities would get a lot of the fellows outdoors for healthy activity, instead of sitting in their rooms at a drinking party. There was an awful lot of drinking. Everybody did it, including the supervisors, so I guess maybe they didn't see any reason to change it.

Working at the Coya Power Plant: Assistant Hydraulic Engineer

Reed: It was a big improvement when I moved to Coya. In the first place, we had a nice house with a garden all around it, with fruit trees and a river running right by there. After work I could walk out within an hour's time and be hunting quail or partridge (*tinamou*), or jump on a horse and go somewhere, and weekends I could go fishing. There was a nine-hole golf course with a swimming pool at Coya. On the weekends everybody from Sewell jumped on that *autocarril* and went to Coya over the weekend. You could even go

down just for the day on Sunday and come back Sunday night. The Coya Country Club was the center of activity on the weekends.

Swent: Did your wife play golf?

Reed: Some. We both tried. My golf was horrible. I think my goal was to complete nine holes in under a hundred. [laughter]

Swent: Your Scots heritage didn't come through there.

Reed: No. I never visited St. Andrew's. I used to laugh at my dad. About the time I was leaving here, he was beginning to take up golf. I thought to myself, as a young person, that golf was an old man's game. "I'll play golf when I'm old and can't do anything else." Well, I got down there, and there wasn't much else to do, so I started trying golf, and I found out there's more to it than meets the eye. It was fun, because you got out of doors. It was a beautiful setting, because it was on a kind of a plateau in the bottom of this big valley, with these huge snow-capped mountains all around. In the spring, especially, you'd have beautiful warm, balmy weather, with this fantastic backdrop. It was a great place, and still is.

I finished up in the mine with the assistant mine foreman's job, and then I went to Coya and spent nearly the first year finishing up the installation of that generator. Then I became the understudy for this older man as his assistant hydraulic engineer. My duties involved patrolling the big canal on the Coya River that brought 750 cubic feet of water a second snaking along the side of the hill until it finally had 430-odd feet of head and came down penstocks into the powerhouse. We had to maintain that ditch and repair it now and then and so on. I remember once we painted the insides of the penstocks, which are six feet in diameter--great big steel pipes. I had to go in manholes with the men and hang on ropes in there, because it's like this [demonstrates], and sandblast it all and then paint it with some kind of a hot bitumen or tar paint-enamel stuff, very smelly stuff.

Then there was another powerhouse. A little ways above Coya there was a fork in the river, and the Pangal River came in. The intake for the Coya powerhouse was farther up than that junction, so it came out of the Coya River. But the Pangal powerhouse was up this Pangal River, and when it discharged its water, it came down the Pangal River after the discharge, and then down the Coya River and right by in front of the discharge of the Coya powerhouse. Actually, the discharge from the Pangal powerhouse was higher than the intake of the top of the penstocks in Coya.

The last year I was there, somebody got the notion--I'm sure it was an old idea--that to make more power they would take that water as soon as it discharged out of Pangal into a pipeline, bring it along the side of the hill over on that side of the valley until they were opposite Coya, then make a pipeline--an inverted steel siphon, they call it--down and across the river and back up, and dump it into the Coya canal. It would go into the forebay at the top of the penstocks, and we'd use the water twice.

Swent: Make double use of it.

Reed: Yes, wear the water out! Indeed, that came to pass.

So they were building that pipeline, and I was busy working on the project when I got sick. When I went back the following year it was working; it was all done.

Learning about Pelton Wheels

Reed: The Pangal powerhouse was where I learned about Pelton wheels.

Swent: I was going to ask you about that.

Reed: Yes, because that was a very unusual powerhouse. The hydraulic head there was sixteen hundred feet. That was a much steeper canyon, and the intake was at an elevation of about six thousand feet. The river came down over what I think was a terminal moraine; it was a great big drop in the bottom of the canyon. The water came along a pipe high on the valley wall, then went through a tunnel, and finally popped out of the top of the mountain sixteen hundred feet above the powerhouse. The three penstocks were 24-inch diameter at the top, but at the bottom the pressure was so great that they were eighteen inches in diameter and about an inch and a quarter thick so they wouldn't burst. An interesting thing about those penstocks is that they were wrought iron, made by the Krupp people in Germany--the people who made the Big Bertha, the big guns--and brought over to Chile and put in way back in 1920 or so.

They drove three Pelton wheels, and the wheels were eight feet in diameter. There were about sixteen buckets on them, and each bucket was bigger than a bushel basket, solid-cast stainless steel. They had been brass, but that eroded too much, and they had converted to stainless steel. They weighed about a ton each, about so wide [demonstrates] and that [demonstrates] deep, and about that [demonstrates] thick. There were sixteen of them spinning around

about 450 rpm--a horrendous speed--and eight feet in diameter. The nozzle, if I recall, was about six inches in diameter and putting out a solid jet of water at sixteen hundred foot of head, hitting those buckets underneath and spinning them around. Then the water went on out into the river.

The buckets were all bolted to this wheel, which was a solid slab of steel, as I recall, about six inches thick and six feet in diameter. There were these huge bolts, about four inches across, bolting through that--about four bolts on each bucket to bolt it to the wheel. Once, during the time I was there, something let go, and one of those buckets let loose. With all that mess rotating, that wheel stopped in less than one revolution, if you can imagine. All that force built up in there like a huge flywheel, and it jerked the whole shebang off its foundations and set it cockeyed. Several of those buckets went clear up through the roof of the powerhouse, which was high overhead. It was a four-inch thick concrete slab roof, and the bucket went so high in the air above the roof that when it came back down it broke the roof a second time. The turmoil was something else.

And nobody was hurt. They were all back in the control room looking at this through a window, and nobody lost their cool. You can't shut that thing off quick, you know; you've got to do it slowly. Of course, there was all hell breaking loose out there, water going everywhere, but nobody was out there in that big room. They got it all sorted out.

That's why I got real interested in Pelton wheels. I never knew, until I visited Grass Valley about three years ago, that there was a whole technology using Pelton wheels in miniature before there was electricity. They didn't have an electric motor to drive a grindstone, for example, but they had a tiny little Pelton wheel instead, and it was direct; it spun the grindstone. When you wanted power, you turned on the valve. When you were through, instead of throwing off the switch, you just closed the valve and didn't use the water any more. They had them all sizes. Some of them ran a compressor directly, and the air went in the mine. Some ran pumps, the hoist, or whatever--any machine. I didn't know that whole technology existed, and that's why I thought that surely there must be a book around somewhere. There's a museum in Grass Valley with all these various sizes of Peltons and pictures and so forth.

Swent: They've got some huge ones on display up there.

Reed: Yes, and ultimately they became used for driving generators, as we do now. There was a man named Pelton who invented the whole idea here in California.

I really enjoyed life in Coya. I was prepared to stay there probably another six years or so, until my kids would be running through the school level available on the company property, and then come home.

Swent: How many children did you have born when you were there?

Reed: Two, John and Robert. When I got sick, Bobby had just been born a year before. He was born on the eighth of February, and he was almost born an Ecuadorian. My wife was several months pregnant when we came up in that September of 1948, and by the time we went back down in January, she only had about a month to go. Everybody was being quite solicitous, obviously. We were going along over Ecuador, somewhere between Panama and the next stop, Lima. What kind of a plane would it have been? I guess a DC-4. I think she got up to go to the restroom, and just as she started coming back down the aisle to her seat we hit some air pockets. I can remember the steward--they had male stewards on those flights mostly--and, boy, he was coming down the aisle as fast as he could to try to get to her to help her get to her seat, but he was having a problem, too.

All of a sudden we hit a big bump, and she just took off, up in the air--it seemed to me a foot or so off the floor--hanging onto a seat or something. About that time he got to her and just kind of put his arms around her legs and got her back down and into the seat. Everybody was really solicitous then. We thought we might have an emergency in the air [laughs]. So we almost had an Ecuadorian for our second son. But nothing developed, and we got safely to Coya. Then she went up to the hospital in Sewell to have the baby. I was working on a water tank in Coya when I got the call--right at the railroad station, as a matter of fact; not over in the camp, but right above the railroad station. I've got a picture of that water tank, and I've sent it to my son: "This is what I was building when you were born."

Poliomyelitis

Swent: When you were sick, you came up here to the States for rehabilitation. Did your family come up with you, too?

Reed: Oh, yes. They were on the same plane. On the flight coming to Miami they had some of the seats made into berths, so I had a berth; they carried me on. Then I had to change planes and fly from Miami to Los Angeles, and they didn't have anything like that.

They didn't have provision for stretcher cases. Most airplanes, when you come in the passenger door, there's something right across the aisle; you've got to make a right-angle turn, is what I'm trying to say. You can't get in there with a stretcher. So they would have to lift me in a sheet, just kind of pucker up the sheet like a sling and get me around the corner, and then take me on in. I'm surprised they allowed it. Nowadays they always talk about getting a special plane, or they get a military plane, to take somebody who's a stretcher case.

They took me in, but they couldn't sit me up; I couldn't sit up yet. They had a padded plank, about like an ironing board, and they had it resting across the top of three seats against the window. There were two seats on each side, as I remember, in those planes. This thing was right along the window, over those two seats, fore and aft. It was padded, and I was on that. My wife and the two little boys were sitting in the seats underneath me and alongside me. That was a long flight, because it went from about eleven in the morning until about midnight, with the time change. It was a milk run or something, and I don't know how many times we stopped--Texas and all these different places.

But we finally landed safely in Los Angeles, and my dad was all set up with an ambulance at the plane to get me to Orthopedic Hospital. Up here they knew everything to do--everything the Chileans didn't know. At this point I had had seven weeks of this, and I had just laid flat on my back. I couldn't move anything but my left arm. I couldn't roll over; I couldn't draw up my knees; I couldn't shift position in bed. I couldn't even lift my head off the bed. I visualized myself in a wheelchair for the rest of my life; I had no idea that anything would ever come back. So what I needed the most was a little encouragement of any kind.

Dr. Charles Lowman and Rehabilitation

Reed: This old doctor, Dr. Charles Lowman, was famous all over the world for rehabilitating polio people. As a matter of fact, he started the Orthopedic Hospital in Los Angeles. It was an old estate, somebody's fancy estate, on Flower Street. He got the notion of this warm-water therapy pool. There was a big lily pond in the garden, so they cleaned it all up, painted it, and filled it with warm water. The first patients, way back, were taken care of out in the pool in the garden. Of course, by the time I got there they had a pool inside, although it had like a garage roller door, and the end of the pool stuck out in the open air. In good weather

they could open it up, and you could swim outside a little bit. It wasn't a big pool.

They'd take me from my room on the gurney to this therapy pool. There was an old guy there who had an overhead rail against the roof and a kind of a pulley and chain block thing. They had a kind of a duck board affair that sat on a platform and had these hoisting arrangements. They'd lift you off the gurney and put you on that duck board in your swimming trunks, and then they hoisted you up, swung you over the water, and lowered you into the water. The therapist was down there, standing chest-deep in the water. She would float you--of course, you'd float--onto a thing that was like an ironing board that was about six inches below the water. There you lay, with all the gravity gone, you see, and she'd put you through all this range of motions--your arm, your leg, and so on, and say, "Contract this muscle, and now that muscle." Of course, the gravity being gone, suddenly you found out there was something there after all. The greatest thing of all was when they stood me up, with my legs splinted so the knees wouldn't buckle, and I could actually walk on my own power, with water up to my chest, across the pool and back. This was within a week after I got there.

Well, you can imagine. From then on, it was just, "Let me at it." It did seem awfully slow to me, but other people would see the change every week. For the person himself, it's often too slow for him to notice progress. However, now and then you suddenly realize that you can do something today that you couldn't do last week; so then you do notice.

I got to Orthopaedic Hospital at the end of February 1950, and by about June the doctors were sizing up my progress and beginning to spot critical muscles which might require special attention to meet minimum functional needs. One solution to this problem is a "muscle transplant." Actually, muscles cannot be transplanted, but let me explain. A muscle can only contract and thereby <u>pull</u> on a tendon. It cannot expand and <u>push</u> on <u>anything</u>. When we push something away with our hand, the muscle in the back of the upper arm is <u>pulling</u> on a tendon, which goes around a pulley in the elbow and attaches to the bone in the forearm. Tendons cannot be transplanted either, but bone can be; so what is <u>really</u> transplanted is a small piece of bone to which the tendon is attached.

The big meaty muscle at the base of the thumb is called the opponens. It pulls the thumb around (opposite) to face the fingers and thus makes us different from monkeys. This is how we hold tools, a pencil, utensils, and so on, and pick up small objects.

Along about June, a specialist in hands, Dr. Boyes, took a look at me and said, "What we need to do is get your opponens going again." See these two tendons that pull your thumb back? Well, I don't thumb rides very much, so I could do with only one of those. Dr. Boyes unhitched the inner one from up here at the second knuckle, retracted it into the forearm, and then fed it back through the carpal tunnel in the wrist. Finally he hooked it back on to the knuckle where it was originally. Now, instead of extending the thumb backwards, it goes around a pulley and holds my thumb around to face the fingers, thus replacing the opponens on the right hand.

The doc said, "See how good that is? Now let me do that to the other hand." Well, when he did this right hand, in order to get the most out of that muscle and not have a lot of slack in it, he put the cast on with the wrist tightly flexed inwards, like that [demonstrates], so the system would heal up tight and short. Later, in therapy, we worked the wrist back straight, but it can no longer flex backwards as a natural wrist does. That's no big deal as far as writing with a pencil or other small operations are concerned, and my hand can perform other critical functions.

My handicap is spotty and reversed. The right leg and left arm are fairly strong, while the right arm and left leg are much weaker. So I need a strong left arm to push up off a chair, or else I can't get up. Also, to use a cane with a bum leg, you want the cane in the same hand. Well, it works out well for me; I have a strong left arm and hand to help with my weak left leg. I can put my left hand down flat on a chair to push up, but I can't do that with the right hand. To push with it, I must use my fist.

I said, "Doc, you've done a real good job on the right hand, and that's swell. I can use a pen or a pencil now, and that will work good. But let's not foul up the left hand and wrist, because I use it for different purposes. I'll get along with this hand as it is." And I have.

Swent: So he didn't do that?

Reed: No, he didn't do this hand. It's just like it was, with no muscle there. I'm like a monkey on the left hand and like people on the right hand. [laughter] I learned a lot from the doctors and therapists about how the body is put together and how it works.

There is something interesting to relate here about Dr. Lowman. Actually, he specialized in the repair of damaged body structures so as to re-establish stability and function. It turns out that our body is a collection of levers, columns, and beams connected with tendons and pulleys, all powered by muscles acting

as winches or hoists. When Dr. Lowman walked in the first morning to meet me, he looked at my file. Of course, my dad had briefed him, I suppose. He said, "Well, John, I see you're an engineer. You and I are going to get along fine, because I had to go down to USC and study engineering so I would know what I was doing." Literally, he meant that. He had gone to the university and studied mechanics--simple engineering mechanics--so that he would understand the body structure and how it works mechanically.

What Dr. Lowman did for me was relatively simple; but where people were much more impaired than I, he did some really complicated work. Sometimes he had to stabilize them step-wise in a whole series of operations--first their abdomen to stabilize the torso, next the legs, and finally the feet, for example. Sometimes they'd go through five or six operations with six months or a year of therapy in between, but he'd finally get them on their feet. He was a wonderful man and kept practicing until he was ninety-two, still going into the office. There's a museum in the Orthopaedic Hospital to his memory.

After the surgery on my hand, the general intensive therapy continued through the summer in the hospital. Meanwhile, my wife had to learn to drive. There had been no need or opportunity to learn in Chile. By about August she could drive, so I got to go home, and every day we'd drive back to the hospital and get my therapy. By about October I could drive a car myself, if it had automatic shift. Indeed, I remember that on our first expedition we went to Santa Barbara for a weekend, and that was a real red-letter day.

About the end of November, Dr. Lowman suggested surgery on my left leg to help the weak muscle on the front of the thigh (quadriceps) in keeping the knee locked up. The muscles in back, which pull on the two hamstrings behind the knee (and kick up the heels) were still pretty strong. The doctor detached the outer hamstring with a small piece of bone from just below the knee, swung it around to the front, and inserted it into a notch made to fit it in the upper edge of the kneecap. So instead of pulling a hamstring, that same muscle is now pulling on my kneecap and thus helps stabilize the knee.

Well, enough of all that. But it's kind of interesting.[1]

Swent: It certainly was a life-changing experience for you.

You did go back briefly, then, to Chile?

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[1]See Appendix 5, letter to Dr. Charles Lowman.

Reed: Yes, in the summer of 1951 I went back to get our things and try and talk my way back into my job, which I wasn't able to do. We had left with just our two suitcases and our two kids, so the house was sitting there with everything in it, and something had to be done. I went down and held a grand garage sale for a week or two and sold off practically everything except just our dearest possessions.

Swent: Were your parents-in-law still down there?

Reed: Well, they had separatead, and Mom Butler was in the states, but Paul was still in Chile.

[Interview 3: March 23, 1991]

Swent: We had just finished talking about your episode of polio, and you had gone back down to Chile to get your household goods--had your garage sale and so on.

The Policies of an International Company

Swent: I think it might be interesting to talk a little bit about the policies of an international company. You were an American employee of an American company, but it was a separate Chilean subsidiary, was it?

Reed: Technically, I don't know what they would have said, but certainly that's the way Kennecott operated. In other words, Braden maintained an office in New York City, 120 Broadway, but that was also, as far as I know, Kennecott's New York office. That's where I wrote when I started my first contact. Miss Helen Otterstrom had run the place for years. I met her once and wrote to her lots of times. The letter of application went there. I think I told you that (because maybe they were so shorthanded or had such difficulty recruiting and keeping people down there in the mine) if things looked all right to the New York office, they just sent you an application and sent you off to Chile. The people in Chile had no knowledge of anything about you. Well, they may have gotten some advance mailings or something, but they didn't render an opinion or anything like that about your hiring. I never went to New York. We just got on the airplane in Los Angeles; they sent us tickets, and we climbed on the airplane and went straight to Chile.

I always did think, through the years, that because Kennecott had lots of properties up here and had that one down there, it

would have been logical to pick out people up here who had already proved useful in their operations, were familiar with mining, and had demonstrated their ability, and offer them an opportunity to go to Chile. But they did nothing like that.

Conversely, I always figured it would have been sensible for a young fellow to go down there to start with, prove himself down there on one contract, then come up on his paid three-month holiday and accept a new contract, maybe get married, and end up down there for six, nine, twelve years or so. For the kids they had an American school, run mostly by American wives. In fact, they even imported a schoolteacher or so on a contract, but mostly it was the wives of American employees who ran the school. It was up through grammar school, maybe even to the eighth grade. But there was a point where the local schools were not going to be adequate. There were boarding schools in Santiago, which corresponded to high school. There was one for girls, Santiago College, basically American-backed, and one for boys, St. Andrew's, run by British people.

My point is that as far as the employment situation is concerned, a young fellow who had stayed there a length of time--the longer you stay down there, the more detached you are from getting a job up here. If you have to do that on your own, it's a big deal; you're liable to come up here and have to start from the bottom. It seemed logical to me that with a proper company policy you could have been brought up and offered a job: okay, you've given us good service in Chile for six, nine, twelve years; now we've got a job for you in Salt Lake. But apparently there was nothing like that. In fact, they discouraged it to the extreme, you might say. If you wanted a job at Kennecott in Salt Lake City, you could jolly well quit in Chile, come home on your own, go out there and go to the personnel director, and start from scratch.

Anaconda, on the contrary, apparently routinely--at least that's the word I got--transferred people back and forth and made allowances, which I thought was a much better company policy and much more efficient and economic in the long run. In the six years I was there, I knew of about a hundred young fellows who not only went through the mine but did not complete their three-year contract.

Swent: That's awfully wasteful, isn't it?

Reed: That's very expensive.

Swent: Then, when your medical expenses were incurred up here in the States, you ran into a problem with that, too.

Reed: Right. They had been taking out a medical deduction in lieu of insurance. In other words, we all contributed to the medical facilities, as it were, with the understanding that if we got sick or were injured or anything, we would be taken care of in the company facility. Well, that had been going on for six years, and then I got sick. I needed care that they did not have, and I shipped out and came home. When the first bill came from the hospital up in Los Angeles, the lawyers in New York gave us a song and dance about, "You were out fishing; it wasn't a work-incurred illness," and all this kind of thing. You were just out on your own. Fortunately, when I went back down in 1951 I did talk them out of at least a reimbursement of the medical expense that my father had picked up. I will say, in fairness, that they kept me on the payroll until August or September of 1950.

The final touch was when, after getting a master's and a doctorate in mining, I went to the personnel man in Salt Lake in 1955 and talked to him about the possibility of a job doing mining research for Kennecott. He offered me the same thing I would have gotten ten years before, fresh out of school, as if I had not worked for them or gone to school or anything else. That was the final touch. It may well have been that they had washed their hands of me and didn't want to get involved again.

Swent: This is a little off the track, but you were commenting on how foolish it was for all their top personnel at the time of fire to go down in the cage together. It was Kennecott that lost all its top people in a plane accident. When was that?

Reed: Yes, the president, Stannard; the president-elect; and another man. That was right in that time. There was something interesting about that. When I was up here with my wife and my little boy at the end of '48, we had been here all fall, from September to the end of December. We were leaving in January to fly home, and we already had our tickets ready. As I told you, my wife was about eight months pregnant, so we couldn't delay much. We were either going to have a baby here or--. At the last minute, just before we were ready to go back down to Chile, the New York office contacted me. They asked me to consider coming to New York, but mostly to visit a bunch of mining schools around the country to help them recruit young fellows, new graduates, to go to Chile. Of course, I would have liked to have done it, as far as that's concerned; it would have been fun. But under the circumstances I couldn't very well. There was the problem of the family and all our plans made; they didn't leave any time to do that. So I had to politely turn them down.

I remember there are some letters from my dad, where he said it was "a shame you didn't get a chance to go do that"--this was

before the plane crash--"because it would have been a good contact with the top brass in New York." So it was soon afterwards that they were flying in a company plane, I believe, and Stannard was going to retire. He and I think Mr. Parker, the man who was going to be his successor, and another man were going up to see a property somewhere in Canada. I think maybe it was the iron-titanium development in Quebec. Anyhow, they were wiped out.

Swent: I think since that time most companies don't allow that.

Reed: That's right. They instigated a policy then and no longer let everybody get on the same plane together. There is a kind of a parallel to this fire business. The three top men should never have gone together to investigate the fire, leaving the junior man in charge of the general mine office under such emergency conditions.

More About the Teniente Mine Fire

Reed: I didn't tell you this about the fire. The guy they left, the fourth man down the line, had been my first boss when I started at the mine. He was this guy who was--

Swent: Not very polite?

Reed: Not very polite and not the keenest personality. They left him there, and of course he didn't know much of what was going on, either. Very soon after they reached Teniente 5, the smoke came in there, too. I told you the whole mine telephone system worked from a switchboard down there on that level, and the smoke got in there early on. The operator was driven out by the amoke, so all the phones went kaput. Even if I had gotten to a phone, when I wandered into the smoke about noon, I wouldn't have been able to do anything. But I didn't know that, of course.

I never said very much about the three Americans who died, Burney Egemo, George Quinn, and Bill Ferry. They were on Teniente One, where the big main hanging wall drift was wide open, straight from the fire to them, and that was high-velocity air. So they didn't get much warning. The smoke was probably there as soon as the telephone call, and there was no place to go. There were three of them, so we think they left the junior man, the level foreman, in the office, which was right there off the hanging wall drift. The other two, the senior man and his assistant--in other words, the mine foreman and the assistant mine foreman--went out on the level to make sure they got the men off the level. At some time in

this thing, they were having trouble--perhaps they didn't know where those orepass auxiliary ladders were, although they were right outside their office; but they had never been exposed to that, never been educated to that fact.

Now, we must speculate, because there were no survivors. As it turned out, these two foremen went out, getting the men off the level, and they found the smoke was very bad by this time. The *bodega*, the storeroom, was about a hundred yards farther back in from the office--another underground structure, if you will. They went in there because a couple of one-hour oxygen apparatus were kept there. They put them on, and then they went back to get their partner who they'd left in the office. This is all supposition, based on how the bodies were found. We think they went back and found their buddy passed out. They're wearing the two oxygen apparatus, and they're wondering what to do to get him to some fresh air. Anyhow, they were found in a heap, the three of them, halfway over to the *bodega*. We think they were carrying him and got halfway there, and something knocked them down. It could have been the explosion that shocked them, or I have another theory. The one-hour oxygen apparatus, unlike the old two-hour one that's on your back and has a cover over it, is smaller and hangs right on your chest, and it has a rubberized breathing bag like a bellows that is not protected. It goes up and down, right there in front of you. Every time you take a breath you deflate it, in effect, although the oxygen is still coming into it. While you're taking care of that breath, the bag is reinflating. But if they were trying to carry somebody, and pressed the man against their chest, it would collapse that bag. Then when they went to take the next breath, there wouldn't be any air in their mask. This apparatus had a mask and goggles, like a gas mask, rather than a mouthpiece.

They were found on the floor, all together. The two who had the masks on had clawed them off their faces, so you can come to a lot of guesswork. Maybe, like I say, they were carrying their buddy, it collapsed the bag, and in desperation, trying to get air, they didn't realize what was the matter and pulled the masks off to get a breath. But they dropped right there. These men lacked the means to protect themselves and gain time to evacuate. A big mine should be compartmentalized, with doors at intervals, not just one door in a tunnel, a mile upwind. They should have had a door right outside their office in that main hanging wall drift, and as soon as they found out there was a problem they could have shut the door right there. The door that got blown out was a half a mile away, upwind near the fire, and they couldn't get to that. They couldn't have gone upwind through the smoke to shut the door, even if the door had not been blown out. A big ship is all divided into compartments, and when someplace gets damaged, why, they shut all

the doors and the ship doesn't sink; things can't flow. I mean, if you have enough doors, the people trying to save themselves will shut the doors and then go the other way. That solves two problems: it keeps the smoke away from them and gives them some time, and it snuffs out the draft on the fire. That's what this thing needed, was to shut the draft off. There are a lot of lessons to be learned at a terrible price that was paid in full with 354 lives.

Shaft 2 was a small internal shaft that went from Teniente 1 to Teniente C, and it was just outside the Teniente 1 office and the door into BNN level. It was not isolated by doors, as all shafts should be. Had it been, all the men lost from Teniente 1 could have taken refuge in its station, shut the door, and been hoisted (or climbed four hundred feet of ladders) to safety on B level and out through BNN. Also, a door in each main HW drift, just outby (outside) the offices on Teniente 1 and B levels, would have been closed by the men there right after the alarm, and thus would have assured time and safe passage through BNN for all the men lost from BN and BS as well as those coming up Shaft 2 from Teniente 1.

VI STUDYING AT BERKELEY FOR A PH.D. IN MINING, 1951-1955

Swent: After you came up after your garage sale, you were on your own at that point. So then you went back to school?

Reed: In the beginning of 1951 I started at UCLA, but then I got this call from Bernard York to come up to Berkeley and start teaching right away. I taught a simple course or two in the spring of '51, and then I felt strong enough to go back down to Chile by myself and take care of that problem. In September of '51, I started working on a master's degree with Professor York. (Professor Weeks was dead by this time; he had died of a brain tumor in about 1946.) Incidentally, even before I got sick, I had been thinking of coming back and doing graduate work, and corresponded to that effect with Weeks and some of the geology profs, so it wasn't a sudden inspiration that I got when I got handicapped, although that made it even more imperative. But I had been looking into it.

I have a letter--and these are the kinds of things you and I have to look at, because some of those letters are kind of significant--I wrote to Professor Weeks early on, in '45 probably. He said, "Well, you can probably come back and do graduate work, but I wouldn't recommend it in mining. Do it in geology or milling or something like that," implying that there was no purpose in an advanced degree in mining engineering. And that's the story I got right along.

Swent: That's the way they felt at that time?

Reed: Yes. They just couldn't see any percentage in it. In fact, when I got up here I shared an office in the basement of Hearst Mining Building with another young fellow who also was going after a master's and thinking about a doctorate in the uranium business. In fact, your husband might well know him--Al Stoick. He still lives in Casper, Wyoming, I think. He was a long time in Gillette. Anyhow, we shared an office. In 1953 we were both down at the

annual AIME [American Institute of Mining, Metallurgical, and Petroleum Engineers] meeting in Los Angeles. I presented the paper which was my master's thesis, basically. Stoick sat around the table at the mining luncheon with four or five general managers and presidents of this, that, and the other mining company. This young student type was sitting there, and they were asking what he was studying and that sort of thing. He came up with the idea that he wanted to get a Ph.D. in mining, and they just laughed. "What for? What would you do? Who would hire you?" That was the consensus at that time. They saw no idea of research in mining or trying to make anything scientific.

Anyway, to get back to school, I came up and started on my master's in September of 1951.

Research on Failure of Mine Openings

Swent: Was that the paper on the fire?

Reed: No, it was on the manner of failure of mine openings. This was some work that Bernard York had started with a fellow named Bill Bush, who was one of my original classmates. They made models which were eight-inch plaster of Paris cubes. They were weak plaster, and then they jacketed them with thin copper and put them inside a little pressure chamber--a piece of twelve-inch pipe with flanges on both ends--and they pumped up the water pressure on the outside of the model. The opening was through the middle of the block. In other words, it had a model mine opening--a little round hole or a square hole or whatever. They would pump them up until they thought maybe that hole was broken. They had no way of looking inside while they were doing this.

Bush had done his master's thesis on the beginning of this technique. I came along, and because of my interest in the rock pressure--you remember what I told you about the timber and the pillar and all that business--I just naturally got interested in heavy ground and ground support and that sort of thing. It was a natural area for me to carry on where he left off. Of course, York was agreeable to that, too. York had worked a lot, I think, in the block caving mines in Nevada in the heavy ground, and in the Comstock lode. So, again, heavy ground and timbering was his interest.

I went along on that and compared all kinds of different shapes and sizes of openings, including even some reinforcements of the openings with what amounted to model rock bolt type of things.

I also developed a system where I had a eye hole in the end, so while we were loading it I could look through an eye piece and be looking inside the little mine opening while Mr. York was pressurizing the water on the outside. That way we had a better idea of just when it was breaking and at what pressure.

That went into a master's thesis and was written up; it's one of the publications that's in the list. It went into that paper on "Analysis of Mine Opening Failure by Means of Models," with Bernard York. Unfortunately, that published paper did not include a section from the thesis entitled "Opening Reinforcement." Therein it was proposed to excavate openings with care and then reinforce the rock with bolts, instead of placing bulky supports later within the opening. Attached [see appendex] are a few pages from that section of the thesis and a letter of June 24, 1952, to Dr. Van Pelt, President of Montana School of Mines, proposing a cooperative research program in Butte, with actual testing in the Anaconda mines. What was proposed in that letter is essentially what has become known now, many years later, as NATM, the New Austrian Tunneling Method. I have no record of an answer to my letter, but suffice it to say that I didn't move to Butte in 1952.

Swent: Is there any follow-up on this work?

Reed: Well, yes, because then I went on to my doctorate, and basically I continued to use the same equipment, but I modified it some more. I began trying to figure out how to stabilize an opening. We had learned quite a bit and gotten ideas about the shape and size of openings and their relative strength and so forth.

Swent: By opening, you don't just mean the portal, but the chamber inside?

Reed: Right. This is supposed to be a section of a tunnel, for example. Let's say a mine tunnel, or an adit or something like that. Deep in the rock, anyhow. This was an eight-inch cube we were modelling and working on. After we finally broke it, we took it out of this chamber and, with an old saw, I just sliced it right through the center. What I really studied was not either end, but a section right in the middle, so I was away from any end effect, supposedly.

I remember that in my application for candidacy for a doctorate I had to somehow demonstrate or give them evidence--this is the graduate school, I guess--that I had innovative, original ideas. A doctorate's thesis is supposed to be an original contribution to the discipline, so I had to wrack through my mind to cite things that I had invented, something that showed that I was capable of coming up with original ideas. The thesis subject itself has to be original; you're not supposed to plagiarize or come up with somebody else's idea. Since we'd been studying how

the openings failed, the next logical thing to my mind was to figure out how to make a contribution on how to make the openings stronger and less subject to failure, or to prevent their failure. This kind of goes back into rock bursts and things like that, too. It turns out that an opening in the rock--or in any material, even a bolt hole in a steel girder--if there is stress on all the material, it gets concentrated around the opening--the hole--because there's some material that's missing there, and that load has to be carried. It turns out that stress is concentrated very close to the hole, but a short distance into the wall of the opening the stress is the uniform stress in the body of the material, and that material doesn't even know the hole is there.

Mine Opening Stabilization by Stress Redistribution

Reed: What I did then was to try to figure out--and I've called it these different names that are in here [points to documents]--"mine opening stabilization by stress redistribution." In other words, I came up with the idea that if I could make the rock back in the wall a little way carry more load, I would thereby perhaps decrease the stress on the wall of the opening. The opening fails because of the high stress right on the wall, and if you push that high stress back you would lower the surface stress. That's what I was trying to do in my doctoral thesis, and I used the same kind of models only much more intricate, and they had strain gauges buried in the plaster and all kinds of things. I went on three years more with that, and I guess I did in fact prove that, if you pumped the pressure up back in the rock, you thereby reduce the pressure concentration on the surface of the opening. I never really proved that that made the whole opening stronger, but at least it was a step in the right direction, I guess.

Swent: What about strain gauges?

Reed: They were the SR-4 strain gauges, little fine-wired grids in a piece of thin paper, and you glued it onto a surface, for example. You ran a resistance through it, and when that little grid got stretched or compressed it changed the resistance over the length of the circuit, and you measured it very accurately.

Swent: They were quite new, weren't they?

Reed: Fairly new, yes.

Swent: You couldn't have done this without the strain gauges.

Reed: That's right, I would have had to figure out some other way.

Swent: I don't know when they came in, but I don't think they had been around long.

Reed: That's right. I hadn't thought about that. We have all kinds of more elaborate systems now--vibrating wire, strain gauges, and all other kinds. But that was a resistance wire--

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Reed: I buried the resistance wires. I put one on the wall of the opening, and then I had about three more at varying depths back into the plaster wall, in the body of the model. What I was trying to plot was the curve of stress vs. depth in the wall. Instead of this curve just being asymtotic right up to a maximum at the wall of the opening, I pushed up more of a hump in it back in the wall, and that pulled the high peak down on the wall of the opening. That's what I was trying to do, and in fact it occurred. But, like I say, we didn't really prove that the maximum pressure that the opening would withstand had been raised; that we did not prove.

Job Hunting, 1955

Reed: By 1955 I had completed the thesis and started looking for a job where I could apply it. I spoke just a minute ago of Al Stoick's experience in 1953. Both of us were doing the same thing; we kept talking to people in the AIME, and anybody we met, about where you could apply practically-oriented research in the mining industry, because we both felt that things had to be made more quantitative and scientific, and develop new methods and equipment or whatever. Up until 1955 I had never been able to find anybody who would offer me, with an advanced degree and some experience, a job doing active research in mining. The people I talked to--managers and so forth--would say, "We don't see where that would fit in with our operation," or it wasn't worthwhile or something.

I was almost resigned to taking a job teaching. Of course, there were lots of places, because in the academic world a doctorate is the first thing they ask for, and doctorates were scarce at that time in mining. Well, they were putting geologists with doctor's degrees in charge of mining departments because of the academic requirements. I mean, Dr. McLaughlin is an example, although he was as much miner as geologist. But that's the sort of thing. I could have gone to Arizona; in fact, I interviewed at

Arizona, Minnesota, Illinois, and I'm not sure about Utah and Missouri, and I visited those places.

The annual AIME meeting that year, in February of '55, was in Chicago. I thought that would be an opportunity to go and rub elbows, ask around, and look for another opportunity. So my wife and I went to the AIME meeting. While we were in Chicago we took the train and went down to Urbana and visited the University of Illinois. They gave us the red carpet treatment. That's kind of a comical story. It's about a couple of hours' ride on the train, a hundred miles, to Urbana, and I never saw such flat country in my life. It's just like a billiard table. We didn't say anything about it, but remember that I grew up in Los Angeles and was always in the mountains, and my wife grew up in Chile and was in the Andes all the time. We didn't say anything to each other, but I know afterwards we were both thinking, "Golly, this is boring."

We get to Urbana and go through the whole rigamarole. The ladies take her out and the fellows take me out, and they have a dinner party and all the rest of it. After about two days of that we climbed back on the train to go back to the meeting in Chicago. About half way back we looked at each other, still looking at this flat landscape, and said, "This is not the place for us. Never mind the job or anything else; we don't want to live on this flat place."

We got back to Chicago, and I was in one of these meetings. I think maybe mining education or something like that was the theme of the session. I got up in the audience and made some comments that I thought the mining industry needed to get some organized research going, to find new equipment and new methods and so on. Elmer Jones was the division manager of St. Joe Lead Company in southeast Missouri, and he heard me. He got me aside after the meeting and asked if, on this trip, I couldn't come down to St. Louis--it wouldn't have been very far--and visit the mines and talk with his people. I explained that I would like very much to and welcomed the invitation, but we were already scheduled to go back through Minneapolis and visit the University of Minnesota and had our tickets and all the rest of it, so I had better go ahead and do that. Then we could arrange a visit to St. Louis separately in a month or so.

That's what happened. We went off to Minnesota and got the same good treatment there, and then went on home. A little later I arranged the trip to St. Louis, and I visited them. On the way back I visited the University at Tucson, Arizona. There was a man named J. Donald Forrester, who was in charge then at that school, and I could have gone there. That's only about fifty miles from

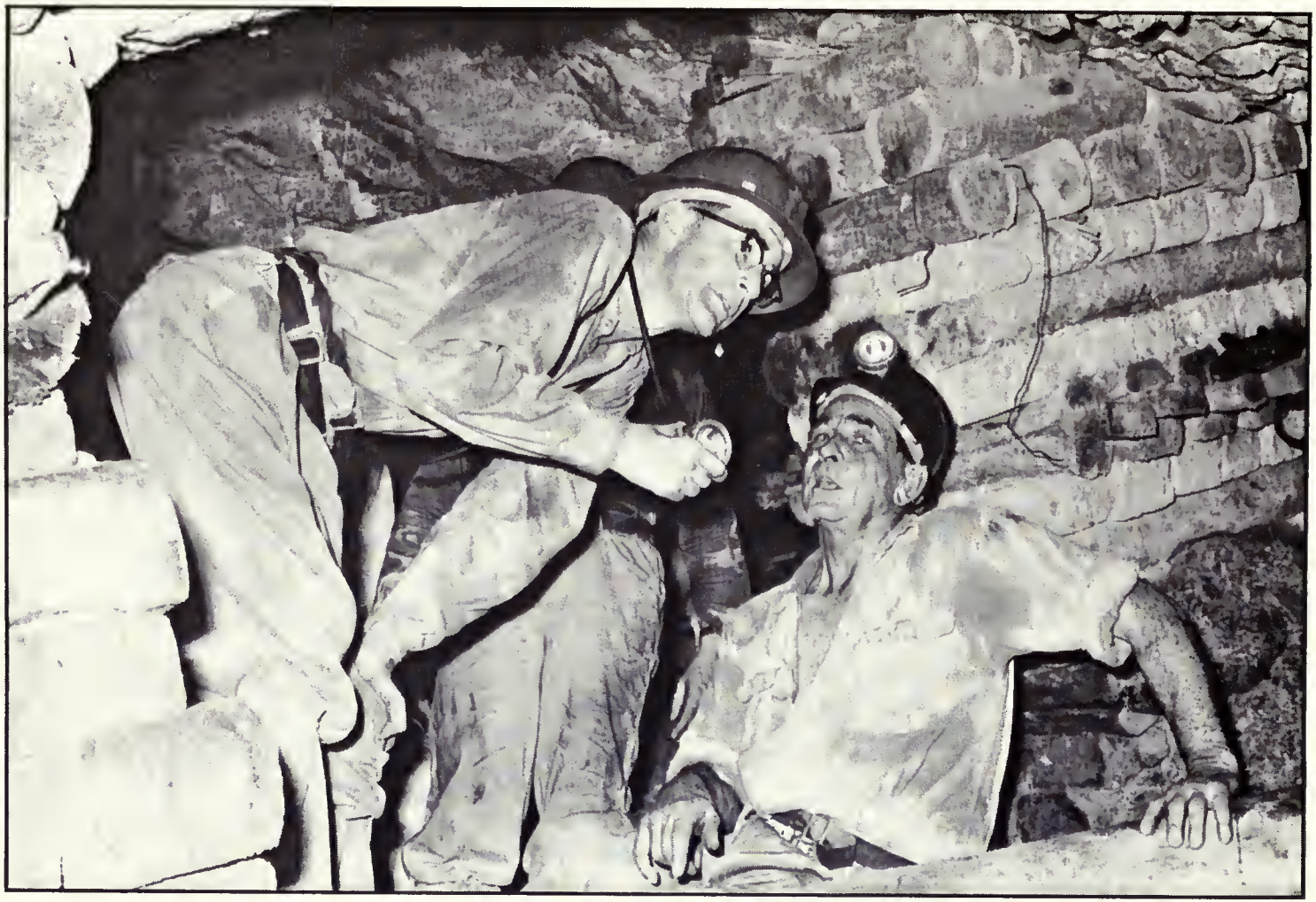
San Manuel mine, and they were just sinking the shaft there, and I went up there just for a visit.

There was something kind of interesting about the thing in Missouri. I think I got on well with all the people. I know I did; I've got a letter to that effect. I talked to all the superintendents and quite a few of the mine captains, and I think they were all willing to have me come, and Mr. Jones was happy about it. But as one last little detail, he said I might as well go by the company doctor's office and have him check me over as part of the whole thing. That was fine, and I went in there. The doctor didn't say anything to me. He looked down my throat and listened to my chest and so forth, probably pounded on my knees with his little rubber hammer and got no reaction. I was pretty thin; I probably weighed 115 pounds or so, and I wasn't a very impressive physical structure. But he didn't say anything or ask me if I was capable of doing this, that, or the other thing. He didn't ask me any questions like that. I came away with no concern.

I got back to Berkeley, and pretty soon I get this nice letter from Mr. Jones. He's awfully sorry, he says. "Everything was fine until I got the doctor's report, and he just doesn't recommend that we hire you because you might get hurt or be a possible cause of injury to others." So he was politely turning me down, for that reason alone. Boy, that was a heck of a shock and disappointment. I thought about it for a few days, and then I wrote him a long letter [see illustration] and explained the work I'd been doing in the lab. I was lifting these big heavy batches of plaster, mixing them, and getting them in the molds; I did it without any help, and I hadn't hurt myself. This had been four years now that I had been getting round and doing lots of things. I said, "I'm a very careful person and safety oriented. I've never had a serious accident before or after I was handicapped. If you'll give me a chance, hire me on a year's probation. Any time you think I'm a hazard or anything like that, just say so and I'll leave, no repercussions. Will you do that?" By golly, he said yes.

So I went, and about a year and a half later he said, "Your job's secure." [laughs] So that worked.

Sewell, Chile, population 12,000. Photograph taken prior to the August 8, 1944, snowslide which destroyed marked buildings and tailings flume bridge.



John Reed (left) and Fred T. Muller, assistant general manager, East Rand Proprietary Mines Ltd., South Africa, then the deepest mine in the world. Photograph taken by W. D. Ortlepp, August 1967.

1211 Carlotta Ave.
Berkeley 7, Calif.

April 13, 1955

Mr. Elmer A. Jones,
Division Manager
St. Joseph Lead Company
Bonne Terre, Missouri

Dear Mr. Jones:

I received your letter of April 7th two days ago, and have given much thought to its message. Although I can understand your conclusions to some extent, I feel that I should point out a few factors which I probably should have emphasized more strongly while in Bonne Terre. I mentioned my slight disability to you because that is the frank and honest thing to do, and not because it worried me. I have no doubt that I can handle the physical requirements of your job as I told you in your office, and when you appeared satisfied, I let the matter drop, as I had not question about it at all.

While Dr. Roebber gave me the usual physical examination, he did not measure my physical capabilities in any way, and my frame, while not much to look at, is still far more functional than it may first appear. I believe that the true measure of my capability is in what I can get done, and not in how I do it. I have no hesitation in saying that I am sure I can handle the work you have in mind with no great difficulty or danger to myself or others.

I have always led an active life; hunting, fishing, camping, mountain climbing, and skiing, and have never had a serious accident in the field or in mining work. I have driven a car since I was 16, and only scratched two fenders early in the game. In view of the above, I can definitely say that I have never been "accident prone", but rather unusuelly well able to take care of myself under many and varied adverse conditions. Since my illness in 1950, I have only become more careful in observing my own limitations, which thanks to a gracious Lord, have now become of minor consequence. Because of this care on my part, which has now become completely second-nature, I have had no serious set-becks or accidents during my convalescence and first few years of normal activities.

Here at the University I taught a year course in ventilation and mining machinery,which involved handling machinery and equipment in the school adit and laboratories, with little assistance. I have mixed and cast some 95 plaster models for my mine-opening studies. Each of the batches

weighs about 70 pounds, and must be removed from the mixer, carried, and lifted onto a table before pouring. For a year I was directly responsible for the operation and maintenance of our adit here, which is used for instruction in ventilation, surveying, drilling, roof bolting, and timbering. I supervised and helped the students in placing sets and general maintenance in the adit.

I am sure you have received favorable replies from my references as to my character and technical ability, but it occurs to me that you have probably not asked them about my physical capability. In order to avoid delay, I am taking the liberty of asking three men here who are most familiar with the physical aspects of my work to write you directly and state their opinions. They are: Prof. Ray W. Clough, Mr. A.L. Crawford, and Prof. David W. Mitchell. These men have watched me work in the shops and laboratories here during the past several years.

The problems you outlined to me and what I saw in your mines have stimulated my interest greatly, and I should like very much to have a fair opportunity to demonstrate my true ability to you, both physical and technical. I am sure that within a period of one year I can do this, and I urge you to reconsider your decision in this light. If at the end of a year you and your staff are not completely satisfied with my capability, I shall not deserve the job, and shall be prepared to try elsewhere.

Mine is at least the third generation of mining people in my family, and I am dedicated to mining. I have been approached by five different universities with good teaching positions open to me, but I prefer the challenge of your "bold venture" in mining research, as I have long been sold on its ultimate value and the need for it.

Please give me a chance to prove myself. I will not disappoint you.

Yours very sincerely,

John J. Reed

via airmail
special delivery

VII HEAD MINE RESEARCH ENGINEER AT ST. JOE LEAD, 1955-1960

Swent: You were hired to do research?

Reed: Yes. St. Joe had had so-called research departments or experimental departments through the years at different times. They were an innovative company. They had developed rock bolts way back in the twenties and used them all over. In fact, it was St. Joe Lead's rock bolting that the Bureau of Mines had a look at during the war [World War II], and right after the war the Bureau of Mines started promoting rock bolts, and that's where it came from.

C. DeWitt Smith had been in charge of this experimental department quite a few years before I went there, and then it had died away. He left, and the department had been allowed to go defunct. What Mr. Jones decided was that he would make me head mine research engineer, with my own little department. He had two young fellows hired, Dick Bullock and Joe Yancik, who had just finished master's degrees at Rolla [Missouri School of Mines]. They were to be my two assistants, and we had a male secretary. We were given a wing off the end of the main office building in Bonne Terre.

When I got there, Dick and Joe were getting acquainted with the mines, and that was my first chore, too, to go around and get to know the mine captains. Each section of the mine was set up as if it were a separate mine, but they were mostly all connected underground. They used the old Cornish term of mine captain for, really, a mine foreman or a section foreman. They ruled their little enclave completely independently and were responsible for it. The first month that I was there I would arrange to go to one mine captain's headquarters each morning, go around with him, and get acquainted with him and his mining system. Some were oldtimers, some were young fellows, some were graduate engineers--all types. Some were very receptive to me, and some were not.

But I got acquainted with them and their system and the mine that way. Incidentally, eventually, when I'd get an idea and we'd try something out on our own, we'd want to take it into the mine and give it a real test. I had to pick one of those mine captains and try to convince him to let us try. Well, Elmer Jones told me, when I first sat down with him, "This is Missouri. You've got to be shown here, and you're going to have a hard time convincing any of these old characters that a new idea is worth a hoot. You've got to show them." What I also found out for myself was that of all those twenty mine captains, I only needed one or two who were receptive; I didn't have to convince them all at once.

Indeed, I tried to pick a receptive one and, "Let's try it in your section." Boy, that was really effective. It was comical how, when I got the wrong one I didn't get too good a test of an idea; but when I got a good idea and gave it to the right young eager beaver, man alive, he made everybody else look sick. New, high quality drill steel was one that worked that way.

Systematic Rock Bolting

Swent: Can you be more specific? What were some of the ideas that worked? Of course, they wanted immediate production results.

Reed: Of course, and so did I! I didn't want to just wander around doing basic research that might turn up useful fifty years hence. I wanted something right now. One of the things was the rock bolting. In spite of the fact that they sort of invented rock bolting about 1920 and had been using it for years, they used it very selectively. The bolts they used they made themselves--a one-inch round, mild steel bar which they bought in carload lots.

Swent: What is mild steel?

Reed: Just ordinary steel, not a special alloy. They would decide they wanted, say, an eight-foot bolt. It was a one-inch bar, and they'd cut threads on the end of it, so they would be one-inch cut threads. Well, you know, that takes away some of the metal when you cut the threads, so now, really, the active size of the bar is the root of the threads. Already you've thrown away some of the strength of this bar that you're going to use when you cut threads on it instead of rolling the threads. You can cold roll threads, in which case you don't take away any steel, and the threaded section is still equally strong. But they didn't; they cut threads.

Then on the other end of the bar, for an anchor, they just took a blow torch--a cutting torch--and burned away a slot in the end like that [demonstrates], about six inches long. Again, they were actually burning away some metal, an eighth of an inch wide or so, so both ends of the bolt were now weaker than the middle. Then the way they anchored it in the hole was with a steel wedge about six inches long and about an inch square on the big end, down to a knife edge. When you set this bolt, you first drilled the hole. Say it was an eight-foot bolt, you'd drill a hole about seven and a half feet deep. You had to drill the hole an accurate depth, and when you wanted to put the bolt in it you put the wedge stuck into the end of the slot, and you carefully slide the bolt up the hole until the wedge fetches up against the bottom of the hole. Then you have to put a driving dolly--a piece of steel, a tool--that on one end will screw onto your bolt's threads, and on the other end will go in the chuck of a rock drill; it's hexagon, in other words, and goes in the pneumatic drill. You turn on the drill, and you drive the bolt over the wedge; that is what you're doing. Because the wedge can't go anywhere; it's got its behind up against the rock, so you're driving the bolt over the wedge and spreading these two leaves of the bolt at the back end. That gives the anchorage.

After you've driven the bolt like that, then you stop and unscrew this driving dolly and put, say, a six-inch plate, or whatever you want to go against the rock face, like a big washer, over the threads and up against the face. Then you screw on a nut and use an air-powered impact wrench to tighten it up. So you tension the bolt between the anchor at the back of the hole and the plate against the rock face. It's a very crude bolt, as a matter of fact, and they hadn't changed it in thirty-five years, making their own bolts and so on.

I started studying it, and, like I said, back about '45 the Bureau of Mines got into this idea and publicized it, and now all the major steel companies like Bethlehem Steel, CF&I in Colorado, and I don't know who all else, made bolts and sold them already made. Their bolts, for example, would be three-quarter inch and alloy steel of some kind--a high-strength steel. They would have a head forged on one end, like an ordinary bolt would have, and on the other end a rolled thread. The rolled thread end was the end that was going up the hole, and it screwed into an expansion shell, like a molly bolt sort of thing. In the first place, the bolts were a whole lot cheaper to buy than to make them yourself. They were lighter. I mean, you buy steel by the ton, and it was a three-quarter inch bolt instead of a one-inch bolt. Everything was better about it. And when you drilled the hole to put it in, you drilled the hole a little deeper than the length of the bolt, and it didn't make any difference how much deeper; you didn't have to

gauge carefully the depth of the hole. Then you just shoved the bolt up there with the expansion shell started on the end and the bearing plate already on. When it hit the face you'd put the impact wrench on and start spinning, and that anchored it and tensioned it all in one go. So it was much more efficient and could be mechanized and so forth.

The way they had been using bolts was very hit and miss. When they decided a few bolts were needed--of course, it costs money to put in rock bolts, and in the mining openings they would mine as much as they could without any bolts. But if they got into a place where the back (roof) was weaker--it'a all stratified limestone or dolomite--then they had a system where they would put up a four-inch channel iron. I think it was twenty feet long, and they'd put that up against the back, with the channel open down. They had three holes four feet apart on one end of the channel angled out about sixty degrees, and another three holes on the other end of the channel, at four-foot spacing, angled the other way. They would put these eight-foot bolts that they drove in and tightened up and all the rest of it, so they ended up in effect making a truss, they thought. They had this continuous steel channel iron against the roof, which would catch small slabs--that's fine--and the three bolts each way up there, but they were only catching, you see, about six feet of roof with an eight-foot bolt because it was laying over on its side.

Furthermore, there was no particular relationship of making a structure between one of these channel irons and the next one over. Each one was a kind of a truss all by itself.

Swent: They were not tied in at all?

Reed: They weren't tied together, they weren't put at regular intervals to put the other dimension in the tunnel, say, or anything like that. They were put in where needed and as needed only. Well, two miners felt they were doing a pretty good day's work when they put in one or two of these things, and that was about twelve bolts, we'll say, in a whole shift's work.

I was studying this and thinking there ought to be a more systematic way, both cheaper and more effective. I might back up just a second to say that Mr. Jones's real interest in my coming there to do research was based on his realization that my interest personally was mostly in rock mechanics, or making the rock support itself, or whatever you want to call it. He was faced at that time with the fact that they had been mining in that area for a hundred years, and they had pretty well mined it all out, all the ore that they knew. It's a horizontal bunch of deposits; they are all anywhere from two, three, four, or five hundred feet below the

surface, but they're just horizontal beds that they've mined. They're under towns and everything, and the extent of the mine workings is about ten miles. Since they can no longer find new ore bodies outside of this area, the biggest reserve they had at the time was the pillars that they had left during that hundred years. In other words, they left roughly 10 percent of the ore as pillars, and that was holding up the surface and the towns and everything else.

Swent: And it's only a few hundred feet deep?

Reed: That's right. In fact, some of it comes right up to the surface. But basically it's strong rock--not completely, but most of it's pretty strong. What he was really looking at was to figure out some practical method to recover those pillars without letting the surface fall in, of course. He thought that was going to be my primary function, figuring that out.

The first thing I thought of working on was to try to learn more about reinforcing the rock, making the rock support more. I thought one approach might be to figure out that if you did bolt the roof, where it had not been bolted at all, you ought to be able to take larger spans. In other words, maybe you could take out half the pillars. You might not take the other half; there you'd be stuck. Also, the lead values were not uniform everywhere. They'd come in long, narrow bodies and round, oblong bodies, and so forth. They might all be ten or twenty feet high cut out, but the shape in the horizonal plane would vary.

Pillar Recovery Using Roof Bolts

Reed: Some places they took me to see, the ore had been in a long, narrow run, as if it had followed a river or something in the rock. It might be seventy feet wide and hundreds of feet long. In that situation, the roof would not stand seventy feet without bolting, so they would mine it with one single row of pillars down the middle of that long room. They took me to see places like that, and here would be a pillar fifteen or twenty feet in diameter and about twenty feet tall. It was rich lead ore, and there it sat. There was a twenty-five foot span on both sides of it, and another twenty-five or thirty feet between it and the next pillar down the row. But there it was.

One of the things I looked at was, "Gee, maybe if we bolted all that roof, then it would stand the seventy-foot span and we could take out those pillars and mine them." To prove this, we

found one of these receptive mine captains and got these new bolts. Also, we really needed work on the efficiency of putting in the new kind of bolts versus the old bolts. In the first place, I've told you that the way they had been doing it they really only caught six feet of rock with the bolt. What we're really talking about here is a bridge span or a slab resting on the sides of the opening, and we're talking about this slab in the roof. So what we want to do is make a reinforced rock roof. Well, the thicker the beam, the stronger it is. They were drilling eight feet, but they were only getting six feet of slab thickness. And, of course, it's harder to drill on an angle, and then that channel iron to handle, and all the rest of it.

I had been reading the Bureau of Mines reports on bolting applications in coal mines and elsewhere, and all they did was put bolts straight up in the roof on some kind of checkerboard pattern, like five feet by five feet, or four feet by four feet. What we came up with, then, was a jumbo, a rubber-tired carriage to do this efficiently. We had some production jumbos available, so we modified one with a drill mounted to drill vertically. Somehow we settled on seven-foot bolts; I think in the particular place where we planned the test the roof was about ten or twelve feet, but by the time you got a drill on end with its carriage and its feed and everything, the longest practical bolt we could put in without changing steel was a seven-foot bolt.

This was a generally-shaped area; it wasn't a single row of pillars or anything. It was a big room that had been all mined out, with a bunch of pillars in it. We decided we'd go down one side of the room and bolt solid from the second row of pillars out from the wall, all around the first row of pillars and right over to the solid wall. We decided we'd bolt on a four-by-four-foot pattern, seven feet deep and with these new-style bolts. When we had it all bolted, we would go down and take out that row of pillars, and thereby increase the span to about seventy or eighty feet of bolted roof.

Swent: You took out the pillars by drilling and blasting them?

Reed: Yes, but first we bolted all around them, clear to the wall. We didn't just leave the roof hanging out there in space. Now, this goes back to the instruments that you were asking me about earlier. After all the experimental stress analysis that I took here at Berkeley, I knew that the rock must deform, move, when you make a mine opening. When you excavate the opening, any rock, no matter how strong it is, moves a little bit elastically and then comes to stability--if it doesn't fall in. But nobody had ever measured that. The Bureau of Mines had just begun to think about instruments to make precise measurements underground.

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Reed: So what we were going to do was take out these pillars, and I wanted to know what happened to the roof when we took out the pillars. Was it going to be safe to go in there? It's one thing to go in and drill and charge the pillar, but the pillar is still there. After you've blasted and it's just a big pile of muck on the floor, and the roof is no longer supported by that pillar, the question is: Are you going to send a loader in there and load that rock out? Is it safe? I had to figure out some way to convince not only myself, of course, but the general mine superintendent and a few other people.

I guess I'll get back to this later, but instrumentation was a big part of what we had to do. We invented and made prototypes and used instruments to make precise measurements of whether the roof and floor had converged. You assume it's the roof bending down, but the floor can come up, also. Nobody that I knew of had done very much precise measuring of rock deformation in mining--or in any other field, as far as that's concerned. It was just beginning to get thought about in those days. We'll talk some more about this.

To get back to this particular experiment with the rock bolts, we bolted for, I guess, weeks, putting in all these bolts. At the same time we were putting in measuring stations all around the pillars and down the middle of this big room, and we were taking readings between the roof and the floor. Two permanent stations would go in the roof and floor with rock anchors, and we were measuring them so that after we shot the pillar out we could come back with our instrument and measure again to find out how much the roof had sagged due to the pillar coming out. Then we watched it for several days to see if it sagged any more. If it sags an eighth of an inch between today and tomorrow because we blasted the pillar, that's fine. But how about the day after tomorrow? Does it sag another sixteenth of an inch, and the day after that another sixteenth of an inch? In other words, is it coming down progressively with time? Is it failing, or is it stable? That, I felt, was the crux of the thing. You need measurements before and after every event and over a period of time.

Swent: You had to go in there to take the measurements, too.

Reed: Sure. That was the risky part, the part where you had to kind of hope you were doing right. But you didn't send anybody else; we didn't send anybody in to start loading the rock or anything.

The first time we did this, indeed we went in, and I think we got a little, about an eighth of an inch. Then for several days or

a week, no more; it became stable again. Then the general mine superintendent, Mr. Turley came down. He had worked in those mines probably for forty years. He and I walked down that long open room together. I had kept the people out; we'd stay back behind the next row of pillars and just look at it and listen. I can remember walking down the middle of that floor with him, with a bar--that's the way a miner does; he bangs the roof, and if it sounds hollow he looks around to see what he can bar down. If it rings and is solid, why, it's all right. That's in lieu of instruments. That's why we were thinking we needed something just a little bit beyond the bar.

We walked up and down that thing, and he just made that bar ring, whanging that roof as hard as he could. He became convinced that everything was solid. Well, it was all bolted together; it was supposed to be solid. We wanted to see how far you could go with this bolting system; we didn't know. There was one end of this room where we opened up--well, it was more than two pillars wide, and we bolted an area that was 100 feet wide and 120 feet long. Eventually we shot all the pillars out of that, and I think that sagged about half an inch, and then it sat there. We loaded the rock out, and we just stayed out of that area then for about six months or a year.

This whole experiment is written up in another article, "A Case History in Pillar Recovery," Transactions AIME, July '59. So the details are in there. Eventually we went back. This big area was really being supported on just a couple of pillars on one wall. After it had been stable for a long time--we knew it was sagging, and of course we didn't hold picnics down in there--we shot out those pillars on purpose, the ones that were over on one edge, because we figured that would trigger a failure. We wanted to make it fail and see how it failed. Indeed, when that went off--of course, we couldn't see anything in the smoke; we went back as quickly as we could, but we couldn't see much. The next day, when we could see, that whole 100 by 120 feet was sitting on the floor, all still bolted together. It just came down as one huge slab, and it sheared off, right around the edge, right up against the wall. It sheared right off, all the way around.

The interesting part was that there was another eight or ten feet of rock that had never been bolted at all, sitting on top of the bolted slab; it came down immediately. You see what I mean, that bolted slab was not only holding up its own weight, it had separated from the overlying rock and was holding at least the same amount of rock more as dead load on top of it. This made us pretty convinced about the strength of a bolted rock roof if--I want to emphasize this--you bolt right over to the wall. But if you just go out in the middle and bolt a roof, it's like holding yourself up

by the bootstraps. You've got to take it over to where it has an abutment, someplace to rest. Actually, the bolting is the most important right up against the wall, because that's where it's going to fail, if ever--where it shears off. So if anything you ought to put more bolts next to the wall. This is completely contrary to a miner's instinct. When he gets way out in the middle of an opening, he worries like heck; but if he's over close to the wall, he thinks he's safe. Well, that's just an instinct or something. In fact, it turns out that technically you could argue that you could space the bolts out in the middle, but tighten them up near the wall. We didn't do that, mind you, but I did insist that they bolt right up to the wall.

The reason I'm emphasizing this is because after the production people saw all this, they said, "Great. Now let's go apply it." So we went to that long run that I told you about, where the pillars were big and real rich--lots of galena hanging out of them; it made everybody's mouth water. I said, "Fine, we'll go over there and bolt it wall to wall, all around the pillars, and then you can shoot out the pillars."

They said, "Oh, no, that's too many bolts. We don't need all those bolts. Let's just put a ring of bolts right tight to the pillar and then another ring five feet out, just two concentric circles right tight to the pillar." Mind you, there wouldn't be anything over to the wall then, and there'd be nothing between the pillars--just two rings around each pillar.

I was against it. There's no abutment for that. You're just holding your hat up. "Oh, that's what we're going to do." Right. Okay. So they did it. We took our rig over there and bolted the two rings they wanted. They shot the pillar, and the roof came right down with it. We never loaded that pillar; it was a great big pile of good ore out there that nobody dared go to. So that proved my point.

I said, "Okay, maybe we can eliminate bolts between the pillars, but when we bolt around the pillar, then we'll bolt a strip on over to the wall on each side. At least you'll have a beam across that way." We did that on the rest of it, and it worked all right.

I will say something else here. This was the particular place where my assistant, Joe Yancik, was using this extensometer that we had invented and built. He went into this place one day--I think it was where they shot this pillar out--and he set the instrument up. It was right after we had shot, and we had to get back to the instrument setting. Remember that we were used to measuring things like an eighth of an inch change. You took notes, of course, and

you'd make a reading today, and then you'd come back and make a reading tomorrow. It's the difference between the two readings. The instrument has a dial gauge that's measuring thousandths of an inch. You take a reading, compare with your notes, and you say, "Okay, it's moved so much."

Joe and his helper were out there, and they set the instrument up. One of them was reading it, and the other one was taking notes. One says, "How much has it moved?" The other says, "It looks like two and an eighth inches." "No," he says, "you must be misreading it." He checked the numbers again and says, "Yes, it's two and an eighth inches." The other says, "Let's figure out what's wrong here, but let's go over behind the pillar and decide; we'll not stand here." So they pick up the instrument and go over behind the pillar. They're looking through their notes, and about four feet of roof, twenty feet long, came down right where they had been measuring. So we found out that two inches was too much. [laughs]

That's the sort of thing we had to try and be very careful with. We never did get anybody hurt. In general we found out that an eighth of an inch, quarter of an inch, or something like that [was safe], but any time you got up to like an inch of motion--and this was kind of surprising--the old-timers, with their bars, would bang it, and if it was hollow or they'd see a crack, they'd get in there and pry it down. We all learned to look at the rock and were looking for loose--for cracks or anything that might fall on us. But it turns out, when you actually start measuring, that you can have a lot of motion in that rock and no visual sign of it. That's where the instruments would help; they give you a clue to what's happening that no amount of experience or eyeballing will give you.

The systematic rock bolting was, I think, a real contribution there. They stopped making their own bolts, and I think they got a lot more--. Incidentally, two men with that jumbo were putting in about a hundred bolts a day--a hundred bolts a shift--whereas before two men had to work hard to get six or twelve bolts in, and that channel iron and all the rest of it. So it made a big difference.

This may be a good point to mention the instruments.

Instrumentation in Rock Mechanics

Swent: Yes, let's do.

Reed: As I say, I'd been reading all this in theory, but nobody had ever made precise measurements in rock mechanics. We had to invent a way of doing it, and we had to go just by estimate and guess and so forth. I didn't know how precise it had to be in the beginning. As I mentioned, there was a Bureau of Mines paper, written I think by Bob Merrill. He had worked in a limestone mine with a very uniform height of opening, and he did some measuring, sort of like I was talking about, except his instrument had a very low range. It's basically a bar that would sit on a station in the floor and reach up to a station in the roof and use a machinist's dial gauge that measures in thousandths of an inch, with a big dial on it. What I'm trying to say is that you couldn't adjust his instrument to read in varying roof heights. It only had the range of the dial gauge itself, which was about one inch. So all his stations had to be approximately the same distance apart; say it was eight feet, give or take half an inch.

Well, in our mines we had places where it was eight feet, and we had places where it was twenty, thirty, forty, fifty, a hundred feet high. I was looking for an instrument which was flexible and yet very precise. I didn't care whether it was exactly twenty feet or not. All I wanted to know was that if it was twenty feet, three and an eighth inches today, was it twenty feet, three and an eighth inches plus or minus two thousandths tomorrow? That's all I cared about. It wasn't the absolute measurement; it was the change, measured very precisely.

There was a great old guy named Lynn Thompson who was an instrument maker. He had his own little shop in the general office building, and he had good ideas. He was a machinist, basically. He was very meticulous, and he liked to make new things, so he and I got on great. Some of these things that I came up with that I say we invented, they were his good ideas that got incorporated. What I was looking for was an instrument that I could set up here on eight feet, over there on eleven feet--you know, reach as high as I could get. I came up with stainless steel tubing that would telescope. Mounted on the top of it was a dial gauge which had a two-inch range.

The big question was, when you telescope it between readings on a given station, how do you know when you go back that you've gotten the tubes back to <u>exactly</u> the same reference point? I'm sure it was Lynn Thompson who came up with the idea of a tapered pin. In machine work a pin is about three inches long, and it's just a gently tapered cone about a quarter of an inch in diameter. If you have reference holes in this tubing and you slide it until the holes match up--and they have been reamed with a tapered reamer, and you drive that tapered pin in to fit--then no matter how it wears, it always <u>centers</u> on exactly the same position. See

what I mean? You can use it over and over, but if you tap it in there, it'll line itself up. It's precise; those two tubes are locked together as if they had never moved. All the dial gauge is measuring is the change up there on top of the tubes.

We made this instrument, and it worked. It worked quite well. It was precise, all right; it would measure a few thousandths change. We did learn that, really, it wasn't significant until you got up to fifteen or twenty thousandths. That's still not very much of a motion, but it was significant. The other thing we found out--we made the first instrument out of 304 stainless steel, and that has a pretty high coefficient of expansion with temperature. It would grab the heat out of our hands and warm up. You could set the thing up on a station and just hang onto it and watch the dial gauge, the heat from your hands would expand the tubing and make the dial gauge go around. We started wearing gloves. We'd set it up, stand back, and leave it alone and let it cool back down to ambient temperature.

Swent: Did your ambient temperature vary?

Reed: No, very little. It was about 65 degrees. We had a thermometer, and we would check that, but it didn't vary much. The amount of heat you could put into the instrument was surprising. It was conductive, and hands are warm, so we learned to use a rag or gloves when handling it.

Going Into the Instrument Business

The Tube Extensometer

Reed: Ultimately, when I went to manufacturing the instruments in Denver, I got Invar tubing because it's a special alloy of stainless steel with a very low coefficient of thermal expansion.

In spite of temperature sensitivity, the original stainless tubing extensometer was very useful. Then we made another instrument using a steel tape system to measure horizontally and also vertically. One of our problems was that some of the mine openings were quite high. The first instrument had the dial gauge sitting on the top of the top tube. Well, if you were in fifteen-foot ground, you had to have a ladder to get up there and drill the hole and put the anchor point in. Then, when you came back each time to take a reading, you had to carry the ladder with you and climb up on the ladder to read the dial gauge. Later we developed a modification, the Model II, which mounted the dial gauge down at

eye level, and you pushed the tubes up to the roof station. That took development, and it worked much better.

We invented several instruments and had a few patents that, of course, were assigned to the company. Later, when I went to Golden and left the company, I thought to myself, "This kind of instrumentation would be used a lot more if it were available off the shelf." I found a machine shop in Denver--the Denver Machine Shop, run by a Mr. Ed White--and I worked with him. In 1963 we were making instruments there to specific order. We'd get an order for an instrument, and I'd design it, the shop made it, I'd inspect it, and then we'd ship it out.

Swent: St. Joe Lead didn't mind your doing this?

Reed: No, I asked them about it, and they said it was fine, as long as they always had access to the technology. In fact, I eventually paid them the money that they had spent for each patent, which was about five or six hundred dollars in those days, and I actually bought the patent rights from them. They reserved their right to use them anyhow, but they never did.

Swent: They weren't interested in manufacturing them themselves?

Reed: No. It wasn't a big money-making thing. I thought it was a contribution that needed to be done, and I don't think I made money on it. I had to invest quite a bit, incidentally, in a minimum order of that Invar tubing. That was the first thing--I made that change, and I had to invest in about $3,000 worth of tubing to start with, enough for many instruments. I sold about a dozen units over time and then came up with other gadgets. I think they were being well received by the mining industry and put to good use.

What I really hoped was that some appropriate big, nationwide outfit with a catalog, like Sears, Roebuck, would come along and take over the idea. Well, in due time Soiltest did. Soiltest was basically a concrete materials testing outfit that made testing machines and all kinds of instruments for concrete work--civil engineering work. I thought, "Gee, that's the answer to my prayer," so I made a contract with them, and they kept me on a retainer for, I think, three years. I would go back to Evansville, Illinois, and see them periodically, take my prototype instruments and help them understand and so forth, and review their production designs. I thought that was going to work out fine, but it was a bust, really. They assigned a guy to my particular stuff who didn't seem to understand how they were supposed to work, and they insisted on redesigning them to look more sexy or something. Then

they didn't check them, and I would find out about it after they had already sold some.

In fact, I had the embarrassing experience of going to Chile later on, in about '76 or '77, and the Chileans had bought one of my instruments that said "Reed Extensometer" right on the side of it, which was fine; I told them that was all right. But they had just received this instrument when I got to Chile, and the darned thing was sloppily made, and it wouldn't work properly.

Swent: Soiltest was actually doing the manufacturing?

Reed: Yes, they took it all over. They bought the Invar tubing stock that I had left and all that kind of thing, and they were doing it. But they'd ship them off with no quality inspection, and then here I had this experience of going down to Chile and this thing didn't work properly. I had to work it over with them there. We got it working, but then there were other things.

A Convergence Warning Light

Reed: One of our little gadgets that was very practical with the miners and helpful was a convergence warning light. When you shot a pillar and had a bunch of rock out there, and somebody had to go out there and load it, the machines made a lot of racket--a loader and a shuttle car and everything else--and this was no time to be worrying about listening to the roof creaking or something. So we wanted something that you could run out there and set up, and it would warn you if the roof was moving. It was expendable, just a couple of pieces of gas pipe with a spring that you could run out anywhere and stick in--just stick it on the floor and up against the ceiling.

It has a flashlight with a red wand on it and a micro-switch--a little switch that very little motion will turn on. You can set this up in a minute and crank it down until it comes on and then back it off just a little bit, so that a couple of thousandths of an inch of motion in the roof will turn on that warning light. Then you go happily about your work and stop worrying about it. If that light comes on, you either run or you can convince yourself, if you want to, and go back over and back it off again--the contact is on a quarter-inch bolt--and turn the light just off again and give it a little leeway. Then you can go back to work, and if it comes on again you can convince yourself that it really is moving, and then get out if you want.

This whole thing cost about ten dollars; it was just a flashlight and a switch. I would sell a little kit, and you could cut your own pipe; there was nothing to that. Well, those darned people at Soiltest fancied that all up until it would cost a hundred dollars, and furthermore they didn't even understand how it was supposed to work. When they got done they had a rigid pipe that wouldn't work anyhow, and they'd been selling them for I don't know how long before I ever found out about it. So, you see, they'd really made a botch of things. I came to the end of the three-year retainer agreement with them, and then it was a question of renegotiating or whatever. At the time it just didn't seem worth fighting to try and stop them or anything else, so I just left it with them. I was supposed to eventually get 5 percent of the sales, but they never got sales up enough to get any more. I got my retainer for three years; that was a guaranteed type of thing. They continued making them up until about 1980, and then they finally discontinued it altogether.

Swent: Did it still have your name on it?

Reed: Yes, still with my name on it. But, shoot, I'd have spent thousands of dollars in legal fees fighting them, and I wasn't about to start with it; it wasn't worth it. I sold some of my own manufacture to Union Carbide for their uranium mines and to the Bureau of Reclamation for their tunneling business. I can't remember all the different people who purchased instruments, but I think it made a contribution to the development of rock mechanics.

Pioneering Flat Jacks and Pre-loaded Concrete Pillars

Swent: What was the flat jack?

Reed: The flat jack is a thin sheet-metal inflatable diaphragm which forms an hydraulic jack of short "run" (under one inch) but practically unlimited area and therefore potentially huge total capacity. I created miniature flat jacks for my thesis work about 1952 and later read of their invention by a Frenchman, Freysinet, for use in prestressed concrete. I read about that and figured the jacks might be an answer to improve a project which had been active at St. Joe between about 1938 and 1942. Back then, somebody got the idea that they could build big concrete pillars in the mine between the rich ore pillars and then shoot out the ore, thus replacing the rock pillars with the concrete pillars. They built a bunch of massive round pillars at the time, anywhere from eight to twelve feet through and right up to the roof. This was in about a

thirty- or forty-foot high area. I think they had twelve of those pillars built in there.

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Reed: At the time they didn't understand, or maybe they understood and simply did the best that they could. In any case, if you build a pillar that just touches the roof and then shoot another pillar, a rock pillar, out next to it, the roof has to move down a long ways in response. Meanwhile, the concrete pillar, to start with, is carrying no load at all, and (this is the theory of elasticity) before it can carry any appreciable load it has to shorten by a measurable amount. So the crux of the thing is that you have to load the concrete pillar against the roof to put oomph back into the roof before you've taken any load off of the rock pillar that you want to shoot out. If you don't do that, then the roof is going to move so much before it gets the concrete pillar loaded that it's going to break up and fall all around the pillar. I don't think they went far enough. This was work about fifteen years before my time, but it was very interesting and we learned a lot from it.

They had gone in there and built these concrete pillars. Of course, you can only get the concrete so close to the roof, and then the roof's in the way. So they stopped about two feet down from the roof, and then they placed big screw jacks. You know what a big railroad screw jack type thing is--big massive things. They set them up all around on the top of that pillar, a regular forest of big screw jacks good for twenty tons each. Then they went up there and tightened them just as tight as they could with a bar.

Swent: To jack up the roof?

Reed: Yes, in effect to jack up the roof and load the pillar--take all the slack out, that's what they were trying to do. I don't know if they gunnited or what, but they packed concrete in around those jacks to make it solid and eventually shot out a rock pillar.

Swent: Was this all going on in France?

Reed: No, this was in Missouri, in the lead mine.

Swent: Oh, at St. Joe?

Reed: Yes, long before the flat jack and all that. This is something that St. Joe had done long before I had been there--about fifteen years before. That was one of the things they showed me on my first visit, and I was very interested. So, they had been pretty forward-looking.

They wanted to know how these great massive pillars they had built were going to load up when they went ahead shooting the rock. As they built the pillars, just inside the surface, about three or four inches into the concrete, and on four sides, they had what amounted to a strain gauge down at the bottom, at the base of the pillar, you went up there and you'd see this little square box with a cover plate on it, like a junction box, in the concrete. You'd open up that box and look in there, and here was a little five-eighths inch stainless steel rod in there, looking up, with a hemispherical top on it. It's anchored in the concrete right below the box. Right above it, three or four inches, is another one that looks just like it, looking down, with a hemispheric end on it. But this one is really a long bar which reaches clear to the top of the pillar, hanging loose in a pipe, and the very top end of it is anchored in the concrete there. So if you measure this little gap of a few inches between the two hemispheres with an inside micrometer--a machinist's tool--it measures the distance between those two within a thousandth of an inch. It's just like what I was talking about before: if the whole pillar gets loaded (compressed) and shortens by a quarter of an inch, say, taking the load of the roof, those two are going to come together. Each pillar was set up with four of these strain gauges around it so you could find out if it was loading equally and take an average and all that kind of thing. They were really forward-looking when they built these things.

They had all these concrete pillars interspersed between the rock pillars, instrumented as described, and they did the best job they could on tightening them to the roof. Finally they ended up shooting out a rock pillar, back in about 1942, and the roof promptly fell in over it. There was a big muck pile, and for years you could see the top of a concrete pillar sticking out of the muck pile. When I first went there, in 1955, I could see it. For a long time they measured all these points on the concrete pillars religiously--for years--and they never found any appreciable compression. They didn't shoot out any more pillars; they stopped. Meanwhile, in the intervening ten or fifteen years, the cave that had formed over the blasted pillar kept enlarging. The big dome up in the roof kept unraveling, and soon another rock pillar over on the side would finally take a lot of weight because it was right under the lip of this cave. It would gradually eat that pillar away, and it would fail, and then the cave would get bigger. The darned cave had gotten huge in this area, and they thought it had blocked itself off on its own muck pile. All the oldtimers claimed that in a cave like this, with the rock falling down randomly, the rock takes up more space in a broken condition than it did in a solid condition. Eventually the pile gets bigger and bigger with

respect to the cavity forming, until it fills it completely and blocks itself out; that was their theory.

Now, there's a town sitting on the top--or, in this particular case it wasn't a town; it was a tailings pond. But there were several other places where the mine workings were under towns. I saw the whole thing as a tremendous experiment that they should be measuring again, because it would give you a clue as to how the stresses in the roof and the deformations and so forth were progressing. So as soon as I got there we started measuring the concrete pillars again. Indeed, the measurements showed that the pillars right under the edge of the cave had shortened about 0.25 inches, and those back one row about half that. Beyond that there was no change, so the deformations are concentrated close to the caved area, as mathematical analysis would indicate.

I had a hard time convincing these people that a cave might surface. They had never had a cave underground come through to the surface, so they just made the assumption, as I just explained, that they never would. I had been reading in British and German technical magazines about mining coal over there three thousand feet deep, and only taking out, say, three feet of coal. They would measure practically three feet of surface subsidence three thousand feet above; they were making accurate measurements on the surface, you know. When I started telling them about that, I said, "What makes you think--your rock is different rock, sure; it may take longer, and all the rest of it, but if you've got twenty feet down here and it all caves in, I think sooner or later there's going to be something on the surface." Indeed, eventually it did; under this tailing pond it broke through to surface and proved my point.

I guess you might say that ultimately I don't really think there was much practical way of getting all those pillars that they had hoped to. Meanwhile, they found new mines--new ore bodies--and abandoned that area and went to Viburnum, fifty miles away, and started mining fresh. But I think we learned a lot. Incidentally, though, there were places, like at the bottom of a main, important shaft--oftentimes there'd be a big shop area there, where they repaired equipment underground so they didn't have to hoist it out. Of course, the shafts are very important in themselves, because that's where the ore is hoisted out and the men come in and so on.

When one of those areas where a shaft goes right down into a big, continuously open, mined area, and when the pillars around the shaft bottom begin to break up or show weight, it's a big investment risk; you can't just walk off and leave it. So they had come up with the idea of building some concrete pillars to reinforce such an area and save it. One fellow there had got the

idea of making these pillars in the form of pre-cast disks, like big poker chips, if you will, a foot thick and six feet in diameter, out on the surface, and bringing them down and stacking them--make a concrete base and then stack them up until you were close to the roof. They had, incidentally, a two-foot hole down the middle; they were really donuts. When you got them all up, then you'd pour concrete in the hole and tie them together. Again, he was thinking about jacks or something to make the final seal to the roof.

Well, I was convinced by this time that the screw jacks and all that kind of thing wasn't practical, and I'd gotten onto this flat jack idea. I thought, "Why don't we place flat jacks, almost the same area as the whole pillar, in the bottom of the pillar as we build it, and then stack all these things on top of it and do the best chinking job we can at the top with gunnite. When the pillar's all cured and solid--as solid as we can get it--we'll inflate the flat jacks down at the bottom, and that'll just jack up the whole pillar against the roof and preload the pillar. Then, using a multiplicity of flat jacks, all inflated with water to start with, when we get it as loaded as we want, we'll cut one jack at a time out of the system, flush the water out, and replace it with grout." The flat jack, you know, is just a diaphragm; it's two sheets of thin, mild steel, really, with a flexible edge. So it's a large area jack, is what it amounts to--a hydraulic jack. We could just jack up the whole pillar. If you do it one at a time, as I've said, replacing the water with grout, when we got all done that would solidify and would become a permanent part of the pillar, and we'd have the pillar preloaded.

We went ahead with that experiment, and that's all been published. It's been published in three different places: the ACI, American Concrete Institute; for the civil engineering people, the E&MJ [Engineering and Mining Journal]; and at a rock mechanics symposium in Pennsylvania.

The first thing we accomplished was to find out that those stacked donut pillars weren't worth a darn. They broke up very quickly under our loading system, because they flexed, and the disks weren't well bedded; they had cracks between them. We tried mortaring them and stacking them up, like mortaring bricks, and that didn't work. Finally, we pretty well disproved the idea of precasting and started making pillars right in place.

Another thing, they used very watery concrete in the mine in their normal concreting work so they could blow it into the forms with compressed air. They had never run any tests on the strength of the concrete that they were making. They'd claim, "Oh, it's

good concrete, 2,000 psi concrete." I had learned in Chile to place concrete as dry as possible for maximum strength.

I said, "Well, let's just start taking some test specimens." I bought a little simple testing machine for my laboratory--I had a little laboratory that I had set up--and we started finding out that the concrete that they were making was actually 500 or 600 psi; it wasn't any good at all.

So we started controlling it and cutting way back on the water, controlling the mix, until we finally were making 6,000 psi concrete. We made, again, some six-foot diameter pillars, just like the pre-cast ones, but we made them in place--poured in three-foot lifts, and we instrumented them. Finally we developed pillars so strong that we couldn't break them with the flat jacks. We made everything so strong that finally the weak link was the flat jacks, and they started popping. I believe we really made the first pre-loaded pillars. I hope there are some places elsewhere that they will be used.

Another thing, in some of these areas we started running tailings from the mill down through a diamond-drill hole and back-filling an area so that the sand ran in around the weakened, fractured rock pillars. That became the best way to stabilize the area. It was relatively cheap, and it really did hug the pillars and stopped them from breaking up.

Swent: Do you know if any of these things have been used in a lot of other places?

Reed: No, not in America. In Europe, yes, they've used flat jacks. Of course, they were using them not in mines, but in prestressed reinforced concrete work. One place they were used in this country as a result of my consulting--at one point, when I was with the School of Mines in Colorado, I was doing lots of consulting. The Bureau of Reclamation, which is right at the Federal Center, was getting ready to make their first attempt at an underground hydroelectric powerhouse at Morrow Point Dam on the Gunnison River in Colorado. One summer I went over and worked with their engineers most of the summer in the design of this underground chamber--how it was going to be rock bolted, reinforced, its configuration, and all that kind of thing. Then I went down there when they started excavating it. And they were using instruments to measure rock deformation.

At one point one wall developed a flaw and began to move in, and it moved in something like two inches eventually. They jumped in and put in tension cables, thus bolting it together with, in effect, long rock bolts or cables. As they were finishing up the

construction--an underground powerhouse is about a 150-foot high excavation to start with, and maybe sixty or seventy feet wide. Then you start putting the turbines in the bottom, and you fill about a third of it up with concrete. The final concrete is the generator floor, which is a big reinforced slab that reaches wall to wall. They conceived the idea of thickening that a little bit so it would be a big horizontal strut across this high walled opening about a half or a third of the way up. To take the slack out of it--again, this business of the slack, of what you put in the opening, is important. They put an array of flat jacks on edge at one end where this slab got over against the rock wall. After they got it all built, then they were going to inflate the jacks to take any slack out of the system and fill them with grout. As far as I know, they did that.

I had to invent a leak-proof grout valve, incidentally, during the work in Missouri, and I've got a patent on that. It's a very simple thing. We made a bunch of those. My brother, Bill, had a machine shop in Los Angeles, and he made them up and we sold them to the Bureau of Reclamation. So that's one application of the flat jack in this country that I know about.

Other people have used the flat jack in another way, for experimental measuring work in rock. If you drill a slot in the wall and slide a flat jack in there and grout it into the slot, then you can pressurize the jack and it will put that block of ground, which is still really in place in the wall, under a known stress condition. If you have an instrument that you're trying to calibrate under those conditions, you can have it in this block of ground that's being loaded. It's an experimental use of the flat jack; it's not the same use as I had. The Bureau of Mines has done that, also.

Developing a Deep Drill Round

Swent: It sounds as if you had a lot of positive developments at St. Joe.

Reed: Well, the biggest contribution, I guess, as far as real economic value goes, was in drilling and blasting the rock. It's kind of comical that in early discussions Elmer Jones said, "Look, we drive a hundred miles of drift every year in developing new ore bodies." This is a tunnel that's about ten feet by twelve feet. "Our miners can drill six feet and blast and break five feet, roughly, in a shift. We've tried and tried to figure out ways of drilling deeper so that we can break more and make more advance faster and cheaper, but you just can't break this rock by anything but a vee-cut round.

You'll probably never figure it out, but it'll give you something to start on. See if you can figure out a deep drill round for our development work. If you can, it'd really be a big value in the development."

Dick Bullock worked on that. I don't know if you know anything about breaking rock with blast holes, but you go to a rock face, and you can't just drill a hole straight into that face, load it with dynamite, and expect it to break. It can't go anywhere, so it just blows out in your face. So one of the systems is a vee-cut. You angle a system of holes, two or three holes on each side, making as big an angle as you can, so you're taking a piece of pie out of the middle of the face. Once you've got that piece of pie out, you've got the relief as deep as the piece of pie goes. Then you can slab the adjacent holes that break inwards to that. They're not breaking out, down the tunnel, but they're breaking in towards the cut. So that's what's known as a cut.

In brittle rock, like quartz or granite, a different cut may work. It's a burn cut, or a shatter cut, or a parallel hole cut; there are a lot of different names, and they all mean the same thing. You drill a cluster of parallel holes, and they have to be very close together. Sometimes it's four or six, but they're only inches apart. You must drill them deep and straight enough so that they don't run into each other or wander off. When you get done--let's say, in this case, you're drilling twelve feet deep. Some of them you leave empty; you don't even put any dynamite in them. They may be, hopefully, oversized holes. One or two you put the dynamite in. Now, they're twelve feet deep, and they've only got an inch or two to an empty hole alongside them. There's no way they're going to break out to the face; they simply break over into that empty hole, and then the expanding gases blow the broken rock, which is very little volume, out of the hole. It comes blowing out of there like a blowgun.

If you're lucky after firing the cut, you may have a little area, say a foot in diameter, clear down to the twelve feet. Now, that is the new free face. You always need two free faces to break rock efficiently: one face to drill into, and another face you break to. What you're trying to create with any cut is a second free face. The rub comes in the kind of rock it is. Real brittle rock, like quartz and granite and such, works pretty well in burn cuts, and they have been used all over the world. But when anybody tried that in this dolomite, it was a soft, punky kind of rock and would recompact in the cut. Instead of blowing the pieces out, it would get plastered to the other side of the open hole when it went off. Then the next hole would go, and that rock would stay in there, too, but always taking up more volume. Pretty soon you'd just have nothing but a hole packed full of crunched-up rock--kind

of frozen, they call it. That's where the round stopped; the succeeding holes had no free face to break to.

We tried every kind of a thing; we tried about a hundred different configurations. We read everything, we went and visited other places. Dick kept at it, and finally he found a round that worked, and it's been used a lot ever since. It was based on three three-inch holes that were reamed out bigger, and three small holes that had the dynamite in them. Another thing is that we used a very slow-acting, low-strength dynamite, because the finer you break the rock the bigger space the broken pieces take up. So what you're trying to do is just barely break it and blow it out of there, not expand it like popcorn. We used what they call a real low-order explosive instead of high-order; in other words, the explosion is slow and heaving, versus hard and fast. We used coal mine type explosive for this reason, to start with, and we found out it all worked.

You also have to leave a lot of time in the delays between the shots in the cut. You use electric caps, and there are delays. They're all energized at the same time, but one goes off immediately, and the next ones don't go off for maybe a second, then two seconds, then three seconds; they've got a built-in fuse in the cap. Well, we found out that you couldn't blast all these holes with instantaneous caps or short-delay caps. They had to be long-delay caps, because physically it took time, maybe only milliseconds, but real time, for that rock to break and go over a couple of inches and then blow out twelve feet and get clear before the next hole went off. That was very important.

It took us a year, but we got it figured out. This was all in the walls of the stope, drilling only cuts. We weren't going anywhere; we were just trying cuts. What was the use of drilling all the rest of a face round and having it fail? That just took a long time and was wasted effort. Finally we built a makeshift jumbo, modified right in the mine shops, that would drill about ten feet, which was the longest feeds we could make. Dick went into one of these experimental areas. In other words, we talked to a mine captain and got a drift that he had to drill anyhow. We got to use it, and the loan of one of his miners. We supervised him, and I forget how many rounds he drilled. It's in the literature. We drilled them ten feet, and we averaged about nine feet of advance. That proved the point.

Then we started talking about ordering a brand new jumbo from Gardner-Denver, built from scratch. This is where Mr. Jones's assistant, Larry Casteel, stepped in. By this time he had been given the responsibility of planning the new mines they were going to develop in Viburnum. They had found these new ore bodies, and

they were going to start from scratch. Larry was a very good, experienced, youngish man. He had been a production manager in the company for a long time. I used to go up and shoot the breeze with him, and we'd argue about the different things I was working on. He'd ask me how it was coming and all. He sat me down and said to me, "John, if this thing is going to work in a drift, why won't it work in a production stope?"

I said, "Oh, gee, Larry, we haven't been experimenting with that; we're not ready for that sort of thing." He said, "Why not? If it'll work--." What we were going to design was a jumbo to drill twelve feet and break eleven, and I was still talking about just a drift, say twelve by fourteen feet. He was talking about a production face that's twenty feet high and thirty feet across and breaks five hundred tons or something like that.

I said, "Gee whillikers, we're not ready for that." He said, "Why not? The principle's the same; we're just expanding it." He convinced me--anyhow, it was his money to spend--so that's what we did. We used a D-4 Caterpillar tractor which mounted three hydraulic booms carrying large drills on twelve-foot feeds.

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Reed: Well, the old miners had been working with column-mounted machines, and the average of all the miners, paid on a contract basis for the rock they broke, was about eighty tons broken per drill man shift, no matter what they did. They even tried some old jumbos at one time, and they thought that was going to increase the production. They spent more money, but it didn't. Then they went to jackleg drills instead of the mounted column drills, a jackleg being a jackhammer with an air-powered leg off the back end of it. That's supposed to be very efficient--less set-up time and so forth--and even with that they were still at around eighty tons per drill man shift.

When our new jumbos got to working with the shatter cut, production immediately jumped to 250 tons per drill man shift in the new mines. In fact, a really good miner could run the jumbo all by himself, and he might break 500 tons in a shift. So you can see that it really made a whale of a difference in the efficiency of the new mines.

Swent: And you were the first people to try that?

Reed: Yes, our little experimental department worked it out. It was dependent upon the burn cut, the shatter cut, that was it. Once we had that figured out, so you could break this second free face

twelve feet deep, then you could break the whole darned room, because it was just slabbing into the cut after it broke clear.

Swent: Were other people in other places doing this same kind of thing at the same time?

Reed: Not in that kind of rock. It was a relatively soft rock and non-abrasive--not a hard drilling problem. But the drills that they had been using, the best and the biggest drills--they weren't very big; they were two and five-eighths bore and some two and seven-eighths-inch bore--were drilling about eighteen or twenty inches a minute. We needed a faster drill.

A German Rotary Percussion Drill

Reed: One of the things I did as soon as I got there was to subscribe to all the mining magazines I could get, at least ones from other countries--Europe, especially. I didn't want to reinvent the wheel; I wanted to profit from other people's developments. So I had publications from Germany, France, Australia, Canada, Sweden, and so on. I got wind of--well, actually I first heard about it from Professor Phleider at Minnesota, who had written an article about a rotary percussion drill invented in Germany. It was pneumatic powered, but had independent rotation and a very high-speed hammer. I started seeing this in the magazines, and we started investigating. There were three different companies that made this type of drills.

Finally we ended up ordering one German rotary percussion drill from the Hausherr Company. We brought it over, and it was just a drill, not a jumbo or anything--a big, massive thing. We mounted it on the front of a jumbo we had, just in a test position, so we could run it up against the wall and find out if it would drill our rock; that was what we had to find out. By golly, it would drill four feet a minute. This was more than twice as fast as what we were drilling. It had various other characteristics that wouldn't work well for us, but it sure could drill.

It was comical, because all the U.S. manufacturers--there's Joy, Gardner-Denver, Ingersoll-Rand, Cleveland Rock Drill, you name it, and Atlas Copco from Sweden--they were afraid we were going to start running the whole mine with German drills. They thought, "Jiminy, we'd better see what's going on." I had to be very careful to schedule the different manufacturers on different days of the week. I'd have Gardner-Denver seeing the drill work on Monday, Ingersoll-Rand on Tuesday, and so forth. St. Joe, mind

you, is a very big mining company, and there were hundreds and hundreds of drills in there, so there was a whale of a market for any machinery that you could get St. Joe to use, and you can bet that they were right there. It was comical. They were all looking at this thing.

Swent: How did they find out that you had ordered it?

Reed: Oh, I was probably talking to them and telling about our testing. The word gets around. It was really comical the way I had to schedule people in. And, of course, we weren't going anywhere with this thing; we were just drilling holes in the wall. But it certainly was impressive. Several of the companies--I know Ingersoll-Rand did, and Joy, and Gardner-Denver; I think they all tried to come up with their own version. Then they'd send them over with a representative, and we'd test them. We'd put it on our rig and see how it worked. Indeed, the ones that did best--Joy came back with one--would keep up with the drilling speed, although something broke in the prototype and they had to take it back and rework it. But that was understandable.

Eventually the rotary percussion drill became the standard drill in this country, and then it proceeded to a full rotary drill. Later drills were fully hydraulic and thus much more efficient than those using compressed air.

Another comical thing about the German drill, it just gobbled compressed air. The ordinary rock drill--our rock drills used about 100 cubic feet a minute of compressed air. The big ones that we had gotten, the newer Gardner-Denver three-inch and three-and-a-half-inch drills, probably used 150 cubic feet a minute, maybe as much as 200 cubic feet a minute. This darned German drill used 550 cubic feet a minute of compressed air. It did a whale of a job of drilling, but it was just gobbling compressed air. And in our old mines, spread out for miles, the air lines had been extended for eons, and all the compressors were on the surface--huge compressors. The main airlines were twelve-inch, ten-inch, eight-inch, and so forth, and finally two-inch out to the drill. Well, there was no way we could get that kind of air to a drill.

It was funny that eventually, after we'd had the drill for quite a while, two German technicians from the factory came over to visit. They were thinking they were going to get a big order. We showed them how it was working, and we said, "You know, it drills like a son-of-a-gun, but its independent rotation uses a lot of air." We didn't know how to hammer except with compressed air, but it was a little light piston, and the hammer alone didn't use a lot of air. It was this big rotary motor that was gobbling the air. We said, "What you need to do is go back home and rework the drill

so you use hydraulic power, which could be very efficient with an electric motor drive and a hydraulic pump, circulating hydraulic fluid for the rotary, and only use air in the hammer." Oh, by golly--talk about stubborn Germans. I've heard this expression [laughs], and I've known some, and Swedes, too, who are real good technicians, but, boy, they're hard-headed. If it's not done their way, or if they didn't think of it, they want to keep doing it their way.

These guys tried to sell us a whole bunch more compressors so we'd have more air. They didn't take into account that that would have bankrupt us completely. We were going towards independent, self-contained units that didn't use compressed air, or a portable compressor to haul behind the jumbo, and we wanted to use diesel and electrical power if we could. So they barked up the wrong tree.

Anyhow, Joy and Gardner-Denver came up with workable, saleable rotary percussion drills, but we were the first ones to actually bring one over here and try it, demonstrate it, and let the people see it. Of course, that stimulated them, and they developed the new type drills.

Another thing at St. Joe--again, it goes back to picking the right guy to try it out for you. Let's go way back. When I went to school here, under Professor Weeks and Bernard York, we had a forge in the basement of Hearst Mining Building, and they taught us how to sharpen steel--how to sharpen a pick, form a bit, and collar a steel for a jackhammer. You heat steel up red hot, and you pound it and get it in shape. Then you heat it again, quench it, harden it, and then temper it. They taught us to do those things, which were really applied physical metallurgy.

Innovations in Drill Steel

Reed: When I get to St. Joe, a long time later--about twelve years later--I find St. Joe is preparing all their own drill steel. In the meantime, drill steel has gone through a big evolution. We used to have plain carbon steel; then they came along with alloy steel. When I was starting to work with these bigger drills, I was looking at something that Gardner-Denver came up with; it was case-hardened drill steel that they did completely under controlled laboratory conditions in their shops in Denver. They sold you a ready-made piece of steel with a taper or a thread on the front end for a bit and a collar on the back. It was such good steel that it had an infinitely long life. Steel in a rock drill fails in

fatigue, because when you pound it on the back end, it sends a shock wave down to the bit, and hopefully it digs a little hole in the rock. But then that wave gets reflected. It goes down the rod as a compression wave, but when it reflects back up the rod before the next blow, it becomes a tensile wave. So really the steel is constantly being--first pounded together and then jerked apart. It fails, finally, in fatigue. That's the big fault of plain carbon steel; it has a very short fatigue life.

Well, when I got to St. Joe they were using plain carbon steel and doing their own forging from bar stock bought by the carload. There was no system to keep new steel separate from old steel, which was full of fatigue and had already failed, perhaps several times, been refurbished, and sent back to the mine. The result was a huge re-circulating inventory of drill steel being carried in and out of the mines and repeatedly being reworked in the shops, only to quickly fail again the minute it went into the chuck of a drill. Each mine captain had two men working full time gathering broken steel to be hoisted out to the shops.

So drill steel was a heck of a problem, and this was with little bitty drills that they were using. I was saying, "Look, when we start using these big new drills on the jumbos, that steel won't work two minutes." In fact, we had kept track. When we were doing this experimenting with the jumbo and driving the drift, we took pains to have them make us new sets of steel from new steel. We kept track, piece by piece, of how long that lasted with the drills we were using, which were only medium-sized drills, and it was very unsatisfactory.

At that point I think I bought some of this expensive carburized steel from Gardner-Denver and tried it in our experimental work, and we never broke a piece. So I started promoting this, then, on a companywide basis. I went to the warehouse section and found out how many carloads of steel they bought a year on average, and I think I came up with about $100,000 worth of raw steel purchased. I didn't know how to find what they were spending in all these shops and in handling, but I said, "Let's just assume that most things are half material cost and half labor cost. You're spending about $250,000--a quarter of a million dollars a year--on drill steel. And it won't work for what we're coming to, either." Boy, I wrote up a report about that and circulated it around. The general mine superintendent, an oldtimer, really chewed me out. He said, "That's a lot of supposition," and so forth.

But, you know, I did get permission to try a little bit in one mine. I went down there to Neil Cooper, who was a young mine captain, not a technical man but a go-getter, and he had a good

level working. I sold him my idea. One of the arguments against the new steel was that one piece cost twenty dollars, and they figured ours cost only nine dollars because we did it ourselves. They were ignoring all the indirect and hidden costs of the old steel.

Neil had fifteen or twenty miners in his section, and for his total new drill steel supply he made a special little rack. It was right outside his underground office. It was a bunch of big six- or eight-inch pipes, welded shut on one end, with a door on the other end, and a padlock, and he had the key in his pocket. He gave each miner one set of this new steel to start with, about three or four pieces, and the spares were all in that locked rack. Those miners were not going to get another piece of steel unless they came to him with the broken piece and he saw it. Also, they were using a slip-on steel bit that they thought was real cheap because it cost only about 20 cents or so. They were so cheap, and they never got dull because it wasn't abrasive ground, that they bought them in barrels and just had the barrels sitting open. The miners took as many as they wanted to, and they didn't keep any track of consumption. As it turned out, the miners would just change their bits every day, whether they needed to or not. We tested them, and sometimes those steel bits drilled faster after they were worn a little bit than when they were new, but nobody was keeping track of that. So that was part of the cost of drilling, too. And you'd find these bits lying all over the mine on the floor; nobody was paying any attention.

I was trying to get them to use a tungsten carbide bit. There was one called the single-use bit, which only cost about five dollars at the time, compared to that twenty cents, but they would drill forever in this ground; you never had to sharpen them. You'd put them on this good new steel, and that was the end of your problems for a month, maybe. So the spare bits were kept locked in Neil's desk in his office. Once in a while a carbide would finally break in fatigue, and the miner would need a new bit. Well, he had to bring the old bit in to Neil, who handed him the next bit and marked it down.

This went on like that, and it was revolutionary. I didn't do any more talking; I let Neil do that. They'd have their weekly mine captains' meetings, and he'd start bragging on his performance. Pretty soon everybody in the mine wanted that good drill steel and those new bits.

Swent: So you put the blacksmith shop out of business.

Reed: Yes, they put the blacksmith shop out of business eventually. But Elmer Jones was right. He said, "You're going to have to show

these people," and I did. I bet you I spent half my time and effort for the first couple of years I was there on salesmanship, convincing people, talking to people, showing people, and so on. I stayed there five years, and it was only the last couple of years that I could really concentrate on research. Salesmanship was a major function for the mine research department.

Swent: I suppose they were suspicious of the "egghead."

Reed: That's right, "This young fellow who's never seen our mines before. All mines are different, you know; you're not going to learn anything in one place that you can apply somewhere else." St. Joe was a very old, stable organization. Well, the average age of the miners underground was about forty or forty-five years. A lot of them had thirty years seniority and so forth. You can understand that it was like a big family. They took care of each other in the Depression, they kept everybody working a little bit part time rather than laying off people, and things like that. St. Joe was a very paternalistic, but pleasantly paternalistic, outfit. I really enjoyed it. It's a shame it was bought out and disseminated and so forth. What's left is now called Doe Run Mining. I think all the old-timers left kind of with their hearts broken.

VIII PROFESSOR OF MINING, COLORADO SCHOOL OF MINES, 1960-1972

Successor to Professor Lute Parkinson

[Interview 4: March 25, 1991]##

Swent: When we stopped talking two days ago you were telling how you got your research ideas put across in the mines at St. Joe Lead. You had been there about five years. What led you to move on?

Reed: Lute Parkinson was then head of the mining department at Colorado School of Mines. I had met Lute in Chile. He had spent his main professional life in Africa, right fresh out of school. He used to tell hair-raising stories about going to Angola to look for diamonds. He'd show us slides of being carried in a sedan chair on the top of two blacks' shoulders. That got him up above the brush so he could see the geology, and that's the way he went through Angola. After x number of years by himself there, he brought his bride-to-be, Margaret; got her shipped down there by boat, and they were married down there. He had a beautiful baby grand piano in Golden with carved wooden legs--an elegant piece of furniture besides being a piano--and that had been her love. By golly, that went to wherever they were in Africa on the backs of porters. He still had that, incidentally, in his apartment in Golden. He was a character.

He worked in South Africa some, too; he was connected with De Beers. All of a sudden, just shortly after the big fire, he showed up at Braden. It was very unusual to hire an outsider for a high level position. He was hired by the New York office, I think. Maybe they thought the place down there needed a shake-up, too; I don't know. He was a real high-caliber man. He was sent down there in a new position, smack in the top of the hierarchy. In other words, there was a general manager and an assistant general manager for the whole property, and then Parkinson was stuck in as

a general superintendent of the whole property. So that put him over all of the department superintendents, who naturally were old hands there, and under the two managers, who probably didn't welcome his presence at all; we're pretty sure of that. Yet, he was supposed to kind of make an overview of the whole property--all the different departments. He was a miner, but he was really supposed to overview mine, mill, transport, power--everything.

Well, he was like a rose stuck between a bunch of thorns. I met him when I was doing my thing in the mine one day. He came walking through, and I got introduced to him. Boy, he was like a breath of fresh air. He was a really sharp gentleman--a gentleman's gentleman. He knew what he was talking about and had lots of good experience, and, really, he stood out like a sore thumb amongst all these other characters who were mostly in top positions only because they had outlived all the others and stuck around. Really, merit was not the thing; it was how patient and persistent and thick-skinned you were--at least in the mine that's the way it was.

I cottoned up to Lute right away. Incidentally, he and wife Margaret were very gracious. I haven't touched upon something else that really shocked me when I went down there as a new young engineer. I had gone through quite a bit of ROTC up here, even in high school. I visualized that it was highly likely that I was going to end up in the army. So in my high school, Fairfax, one year of ROTC was required, but I took a second year. I just liked it--not the idea of going to war, but the idea of being prepared and the martial music, marching and drilling, and so forth appealed to me. At least I enjoyed it. Then when I got to UCLA, of course it was required again for a year. I didn't take any more of it there, because it was too much to study. But I did well there, too.

You study in ROTC a lot of things about military courtesy. There's book learning involved. One of the things that was really pointed out, and I became aware of, was that it was up to a young officer, when he's assigned to a new post, to call on the commanding officer socially. Then they are supposed to repay the call, and all that kind of business--military courtesy. Not that this was a military camp down at Braden--

Swent: There are similarities, though.

Reed: Right, and I at least expected that I would be invited out somehow socially. Do you know, it was a year after I was there before anybody invited me to their home for dinner--not even the people I worked with, my direct supervisors; it just wasn't done. The young mine engineers were treated really like scum, and that's part of

this same thing. It was a ridiculous counter-productive situation.

So when Parkinson showed up, Margaret was a gracious hostess, and they invited all the young fellows from the mine staff house down en masse for parties--you know, the ones who had only been there for two weeks or something, and all of us. It was like night and day. So Parkinson was very popular with the young people--the junior engineers--but I think it probably rubbed the others wrong. They probably said, "You're setting an awful precedent; we're all going to have to do this."

Swent: That's really surprising, because at many of these mining camps people welcome any pretext for a party, and a newcomer is an excuse for a round of parties--just for something to do, if nothing else.

Reed: Sure, and this was a big organization; there were lots of people to get acquainted with. Then we were discouraged from hobnobbing with the Chileans to a degree, too. There wasn't much occasion to, but it was discouraged. Of course, we weren't likely to so much, because in the beginning the language problem was there. Anyhow, that was a peculiar situation.

The upshot of it with Parkinson was that after less than a year--maybe nine months--he just got fed up because he saw that he couldn't contribute anything. He was just isolated, and he wasn't really given authority to do anything. He'd write reports and so forth and hand them up, and they'd just get dumped. So he just quit. He went up to Maria Elena in the north of Chile--the nitrate fields--and they lived and worked up there for some years after that. I saw him at the airport when my wife and I went through on our vacation trip up here in '48, so I know he was there until then.

Then all of a sudden Margaret came down with cancer. They immediately took off for the States, and she died within a year. He then stayed there, and I guess he went then to Colorado School of Mines. When I finished the doctorate here [at Berkeley], he wanted me to come to Colorado. At the moment he didn't have a space, and I didn't want to go into teaching immediately. So I got nicely started at St. Joe, and in a couple of years he started bugging me again to come there. I wanted to stay long enough to accomplish something.

Finally the compromise came. My wife and I had been concerned about the schooling for the kids. They were getting older, and this was the Ozarks and kind of rudimentary. Actually, I kind of have a feeling that if we had stayed there the kids would have gotten a better education than they did when we moved. But they gave us a big song and dance in Golden about the modern schools,

and, dang it, they were experimenting, is what they were doing, with all these open classrooms and so forth. In high school, for example, they let the kids decide whether they wanted to go to class or not. You'd go over there to the school, honest, and you'd walk through the hall in the middle of the hour, and the hall was full of students running up and down and jawing. There was hardly anybody in the classrooms. It was pretty discouraging. But we were there by the time I found all that out.

At the end of five years, that was our argument for moving.

Swent: How many children did you have then?

Reed: Four. We had the two boys, John and Robert, in Chile, and then the two girls, Georgia and Patricia, were born here in Alta Bates, right on the edge between Berkeley and Oakland.

Swent: While you were in school?

Reed: Right. When we went to Missouri, we had one, Patricia, who was just a year old.

Swent: How did pay compare between St. Joe and Colorado School of Mines?

Reed: I'd have to go back and check.

Swent: Did you take a big drop in pay?

Reed: I don't think terribly big, no. I was fortunate, of course, with my degrees and my experience and all. In the academic field, you know, you're likely to get started as an assistant professor and take forever to move to associate and all. But I was being groomed to replace Parkinson; he was getting on towards sixty-five. And he knew me very well, so through his efforts I went there as a full professor and--not officially, to start with--his assistant. But that was obviously what I was supposed to do; within about two years I was supposed to take over from him.

Swent: He was a professor of mining?

Reed: Yes, and he was the head of the department of mining engineering.

Departments and Curriculum

Swent: You think of Colorado School of Mines as being all mining.

Reed: Yes, many people do, but in reality the school covers the entire broad spectrum of the mineral industries. The name Colorado School of Mines is known and appreciated worldwide.

Swent: And revered.

Reed: All that kind of thing. I was already aware of this, because the alumni would have reunions in Chile. Later, when I was at School of Mines and traveling around, I saw it in Australia, New Zealand, South Africa--no matter where you went, when you said where you were from Mines--oh, boy, they knew that school.

Swent: Yes, it's very special.

Reed: Right. It is mineral technology, and at that time the six subjects were mining, metallurgy, petroleum engineering, petroleum refining engineering as a separate subject--chemical engineering is really what it amounted to, and later they actually added that to the name; it was a degree in petroleum refining and chemical engineering, all wrapped together. Then there was the geology department, and a separate department for geophysics. Those were the six degree-granting departments. All the other departments--math, chemistry, physics, basic engineering, and there might have been mineral economics--were support departments, and they felt sort of second string because they couldn't grant degrees.

During the time I was there, which totaled twelve years, the math, chemistry, and physics departments became degree-granting departments. In the beginning, all degrees were engineer's degrees, incidentally, as opposed to a bachelor of science. In the academic world you usually get a bachelor's degree after four years, and then there's an engineer's degree, which at the time was two more years here at Berkeley; it was more than a master's degree.

Swent: This is the E.M.?

Reed: Right. But at Colorado School of Mines the first degree was an E.M. There was always a certain amount of bickering in the nationwide educational hierarchy about that degree. If you weren't there at Colorado, you said, "They're inflating their degree," but the students worked awfully hard, and they put in the equivalent of five years in semester hours and that sort of thing. Here [at Berkeley] I think I graduated with 142 semester hours. At that time that was routine in engineering, whereas in letters and science it was 120.

I got back there, and the first degree, this engineer of mines degree (or whatever other department), was about 212 semester

hours. So you can see that it was there, all right; there was a lot more. And they had some other requirements. So the accreditation people--the Engineers' Council for Professional Development (ECPD), which is a cooperative between AIME, ASCEME [American Society of Civil Engineers], ASME [American Society of Mechanical Engineers], and all the rest of them--send a team around supposedly every four years to examine every accredited engineering department in the country that requests this visit, and hopefully gets reaccredited as a full-fledged engineering department. Otherwise they're put on probation or whatever, and they are told they don't measure up. Naturally, nobody wants to be called an unaccredited department.

This is getting a bit afield, but all the time I was there, there was a campaign to get Colorado School of Mines down to the rest of the engineering schools around the country. Indeed, on top of that, the engineering schools in general were being pressured to get down to 120 semester units. You know, it's watering down. All you could do is take out courses.

Swent: Where was this pressure coming from?

Reed: I guess the hierarchy of the ECPD, the engineering societies, and so forth.

Swent: Not the alumni, certainly.

Reed: No, they were objecting to it constantly. We can talk for a long time on that subject.

Back to the organization of the school: finally math, chemistry, and physics--I don't remember when, but in that twelve years--began offering a degree. This is when we went to a bachelor's, because somewhere along the line there you got a bachelor of science in mining engineering. A fellow over in math, for example, would get--they invented a peculiar degree--a bachelor of science in mineral engineering with a second designation of either math, chemistry, or physics.

Swent: This was a master's degree?

Reed: No, it was a first degree, for example a B.S. in mineral engineering-mathematics. He had to take an equivalent of a bachelor's degree in math anywhere else, and he took basic engineering--essentially the first two years, which was common pretty much in all the different departments. So he was a qualified engineer, and he was a good mathematician. Besides that, he had to opt for one of the six mineral departments that I mentioned. If he chose mining, for example, he had to come over

and take about four courses: introduction to mining, mining methods, and a couple more.

So these were very useful, hybrid people, really, in the mineral industry. If they wanted computer experts or good chemists or physicists, if it was a mineral industry effort, these guys, I think, should be pretty attractive. Because you get just a plain mathematician into a mining company and say, "Let's start on applying mathematics to whatever--ore reserves or something else," he doesn't know--the first thing he's got to do is learn something about mining; he doesn't know the terms, even. So in a general way I think it was a good thing, and of course it made those departments much happier. Now they were degree-granting departments, and they could attract better professors, for example, with a future and all that. You know, a Ph.D. in mathematics, up to then, was going to be pretty reluctant to come to Colorado School of Mines; it would be a dead end for him.

This went on, and about the time I left, about 1972, they did the same thing in what was called the basic engineering department. They started letting it grant a degree, too, but it was like "mineral engineering." I don't remember the detail of that one, but the school has gotten much broader.

Swent: You went in as a professor?

Reed: Yes, of mining engineering.

Swent: That was one of these six departments?

Reed: Yes, at that time, one of the six degree-granting departments.

Swent: Did they grant Ph.D.s also?

Reed: Lots of master's degrees, and, yes, we ended up granting Ph.D.s, too.

It just happened that I was scheduled to go there--we made up our minds that we were going to do this about in the summer of 1959. I told my boss at St. Joe about it, and that I would stay until August of 1960. I was trying to finish up and break in Dick Bullock to replace me as head of the department, and looking ahead. It just happened that Lute Parkinson had a minor stroke about June 1960, before I got there. I arrived in August and was just getting settled in when he had a more severe one, which left him still okay in mind, although a little bit bad on memory, and as I recall a little bit one-sided; he limped a little bit, and one arm was kind of half out of action. He was still a sharp character, but he didn't have the oomph any more that he had.

So it turned out right from the beginning that he and I sort of operated the department unofficially as a joint venture. I don't think I had a special title, but instead of giving me an office--well, I did have an office upstairs by myself until this happened--they moved my desk down into the department office. There was an outer secretary's office and Lute's private office off of that, and they stuck a desk in there for me along with the secretary so I could take lots of the calls and take the load off of him. This went along for about a year, and then he wasn't coming around any better. Besides, by this time he was getting close to the sixty-five thing anyhow.

So I was then officially made head of the department from then on, and he went off. He was a most unusual character. He had a brother who lived in Rhodesia and mined chrome--another miner--and after all that, he went all the way over there on his own in this slightly handicapped state, and he visited all his old haunts, even in Angola. He went through all those places where he'd been some thirty-five years before. He had good friends in France. He had worked in the Belgian Congo, so these might have been Belgians living in France. Ultimately that's where he died, in France, while visiting some of those friends, but this was two or three years later. He traveled all around in spite of everything. He was a hard man to put down.

Back to the school--

Swent: Were there many in the department? Did you have assistants under you?

Reed: Oh, yes, we had four or five professors--associates, assistants, and instructors.

Swent: How did they feel about your coming in with little academic experience? You had been an instructor here at Berkeley for two years, but you hadn't come up the ladder.

Reed: I never sensed any animosity. They knew my professional background, and some of them didn't have as much industrial experience as I did.

Importance of Industrial Experience

Swent: You had a rare combination, didn't you?

Reed: That's it. In fact, I've got some strong feelings about that. I think too many people end up in academia, especially in engineering and maybe elsewhere, too, with little or no industrial experience. Here is a man who could end up head of the department of mining engineering, with a Ph.D., we'll say, and he's never worked in industry at all. If you are real brilliant in school, the tendency is to get your bachelor's and then stay there and get a master's, and then keep right on going. It's the least waste of time. It's most efficient; you don't have to relearn how to atudy and so forth. Personally, it was no easy task to come back after six years in South America and start studying calculus and other things that stumped me. Besides that, you're competing with young people who have been in school all the time. That's quite an experience in itself.

I think industrial experience is terribly important. In fact, I toyed with the idea of instigating a requirement for an advanced degree, most certainly a doctorate, to be accepted as a candidate to start a program, a man would have to show at least one or two years' experience in industry. We never got around to that. The British mining schools--the Royal School of Mines, and I'm quite certain Camborne School of Mines--for long years (and I don't know but that they still have it), if you didn't go out and work for a year in industry before you got your first degree, you had to go overseas at least one summer and work. Some of these Royal School of Mines people with three years of school would show up having worked in a mine in Canada, South Africa, Zambia--mostly British colony holdings, because they had an in there. I'm sure that this made them better mining engineers when they came out of school; they knew what they were talking about.

In 1960, while making the move from Missouri to the Colorado School of Mines, I heard of the 7th Commonwealth Mining Congress being held in Southern Africa. As I couldn't attend that one, I began planning ahead, and my wife and I were able to attend the 8th congress, held in Australia and New Zealand during early 1965. These meetings lasted about a month, moving from city to city, with field trips to mines, laboratories, power projects, etc., between cities, and wonderful opportunities to meet and mingle with fellow miners from all over the world.

Highlights included my first visit in a coal mine at Newcastle; underground powerhouses in the Snowy Mountains, Tasmania, and New Zealand; and the geothermal power facilities at Wairakei in New Zealand. All of these experiences and contacts were to prove invaluable in subsequent years, as we developed an interchange of students, staff, and information with Australian mining schools and the Snowy Mountains Authority (patterned after our USBR). The latter, especially, did valuable pioneering work in

the design and construction of large underground power chambers; and Tom Lang, an associate commissioner of the Authority, has transferred that experience to America since immigrating here in the sixties. Working with Tom and his ideas on such projects as NORAD in Colorado and the Portage Mountain dam and underground powerhouse in British Columbia has been fascinating and very educational.

Contacts with South African delegates have led to similar valuable interchanges with their universities and the Chamber of Mines. Discussions of work-study programs in Australian mining schools reinforced my desire to see a requirement in our programs for summer industrial jobs during a B.S. program, and a minimum of one to two years of such employment after the B.S. and before acceptance to an MS or doctoral program.

Swent: Don't most of the American students work summers at least?

Reed: We hope so, but a lot of them don't. In fact, one of the things I did do at Mines was to make a real active campaign to make sure during the spring to get everybody placed. I went out and solicited opportunities from the industry. "Will you take two or three students at this mine or that mine?" Because the students have a tendency--they were working their way through school lots of times--to go where they could get the most money to keep them going. So they were liable to end up in non-mining jobs, like working down in Denver at a bank, which is understandable--maybe they could live at home; Lord knows. They pretty near all worked in the summer, but only part of them were working in anything that had to do with their studies.

Swent: Did you have to convince any of the mines that they could benefit from hiring these people? Was there reluctance to hire students for just a few months? That's quite a responsibility.

Reed: Well, it took a little salesmanship. Sometimes it doesn't do the company much good. From the other point of view, it gives them a chance to size that fellow up, and it might lead to a permanent job when he graduates. If they see that he's a go-getter and smart, then he's an excellent candidate to hire when he finishes.

Swent: I notice that you say "he" all the time. Did you have any women students?

Reed: Very few in the beginning, although now, in 1991, women comprise 22 percent of the student body at Colorado School of Mines. In my twelve years there I only had two women students go through. They both got degrees, and one of them, Elizabeth Gibbs, runs a very active--I see the ads in the paper--consulting firm, doing computer

applications to ore body reserves, mining problems, and so forth, out of Boulder, Colorado. There was another girl who did well and went to work in the mines. It's comical what the industry has gone through. I mentioned early on that I'm surprised now that my father was able to take me underground at the Dome Mine when I was fourteen (1937).

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Reed: I couldn't even take my twelve-year-old sons down on a Saturday at St. Joe (1959), just to ride down in the cage and see the underground shop--not go out in the mine or anything. I couldn't get permission, even as a department head, to take them underground. It was that rigid. Now they have an open house day there, and they take all the wives underground. They wouldn't have done this in earlier days, much less hire a woman. Now you go underground in mines and you're liable to see a woman with a hard hat doing a regular job. It might not be heavy work, although I suppose now some of them are doing practically anything. After all, to run a jumbo or many other machines, they don't have to be physically real strong. In fact, some of the best off-road truck drivers now, and heavy equipment drivers are women, because they don't mistreat the machinery so much. They found over a period of time that the machinery that women operate is much easier to maintain, and that's a big thing--tires, transmissions, and all this--in these huge trucks.

Swent: Somebody has actually done a study?

Reed: Oh, yes. The companies recognize it themselves. Men folks tend to be macho and act just like kids with their hotrod cars, run into the wall in the mine or something like that. So that's been a big change.

Changes in Mineral Industries Education

Swent: You were talking about where the pressure came from to "water down" the degrees at Colorado School of Mines.

Reed: In the ECPD and so forth? In general, the education situation through those twelve years as I saw it, and I don't know altogether what's happened since--for example, when I first went there in 1960, there were about thirty-one or thirty-two accredited departments of mining engineering in the United States. They started dying off for lack of students, lack of staff, and so forth, until by the time I left (1972), there were only about

sixteen. Berkeley's mining department is one of the ones that went completely defunct.

Swent: I remember at one time there were practically no mining students here.

Reed: That's right, and at one time there were none; there was no department or anything. The same thing happened--Washington State had two schools of mines, one at the University of Washington in Seattle and another one over at Pullman. And Wisconsin had two, for some strange reason, and Missouri, Arizona, Utah, and Colorado, of course. But Colorado was always head and shoulders above the others in numbers of students and staff and so forth. Incidentally, Rolla, Missouri--the Missouri School of Mines--was usually number two. But when we had about two hundred students in mining alone, in round numbers, they would have maybe sixty, seventy, perhaps eighty, and all the other schools--the other fourteen or so--might have a handful--six, eight, ten students and two or three faculty only.

Swent: I think some of them, like New Mexico and South Dakota, went to mines and technology.

Reed: That's right--Socorro [New Mexico]. In my estimation that was a mistake. They probably had no choice. It's the same here [at Berkeley]. This used to be the College of Mining; it wasn't even part of engineering. It was Dr. Donald McLaughlin--I think the hierarchy wanted to get mining into engineering, and to get it to happen they offered McLaughlin the dean of engineering post for about a year. So that did it.

That was true of every other school. Montana School of Mines became Montana Mines and Technology or something. Michigan School of Mines--they were all schools of mines, and they all did this. Well, what they became was very secondary--in other words, a small fish in a big pool instead of maintaining their integrity. Like I say, they didn't have a choice, but when you become a small department in a big university--it's hard enough to get funds and students, and this immediately waters it down. This is part of the reason, I think, that they dropped from thirty-two to sixteen schools. Lack of support--of course, without students, how do you get money for professors and so forth? As we started going around and accrediting, we'd come along and find a department that had maybe one professor full time and another guy who was half time in some other department. We had a rule of thumb that you needed three full-time professors to get full accreditation.

Swent: You were working with this accreditation?

Reed: Right, as head of the department there. The visiting committee is made up of volunteers who are picked from other schools of the same subject, so you're really going around and inspecting each other.

Swent: Your peers.

Reed: Yes. But you go in as a team. There will be one person leading the team each time, and there might be four or five people meeting at some school. The head of the group will do some of the inspecting, too, in his field, but there'll be somebody for mining engineering, metallurgical engineering, maybe geological engineering, and so on. Or mechanical engineering and civil engineering, quite apart from minerals, because the ECPD is not minerals only; it's all engineering.

I would always be the team member responsible for mining engineering.

Swent: Which institutions did you go to?

Reed: Oh, golly. I can't remember, but they would include Washington, Montana, Idaho, Arizona, Missouri, New Mexico, Nevada, Wisconsin. I got to practically all of them.

Swent: Did you enjoy this?

Reed: Oh, yes. It was educational, among other things. You knew where you stood, and you could help them. We weren't trying to eliminate competition.

There was only one man who did that, and he was the guy who was the head of the department here at Berkeley. He was a bad apple in the ECPD, and he was a bad apple here. He did this, and he really rode on Parkinson. He would go there to CSM and say, "Oh, this is a trade school," and run them down, and they were turning out better engineers than anybody else. But he was an exception to the rule.

Everybody else I ever knew who went on inspections--sure, you'd come to a real sad case of a department with only one guy and almost no students, and you'd say, "There's no way we can give you full accreditation, but let's see what you need." And we'd try to write strong recommendations to the school's administration about what this department needed to get it back on the full accreditation list. We'd try to give him ammunition to use on his own superiors to get what he needed--another faculty position, more laboratory, or whatever.

Swent: Was there a dwindling demand for mining engineers as well?

Reed: Oh, yes, that was part of it. There were less students coming in; it wasn't popular.

Swent: There is pressure exerted from the industry itself if it needs more engineers, isn't there?

Reed: Yes, although I don't remember a time when our students who finally graduated, regardless of whether you had one or forty, didn't all get interviewed, and much of the time they had a choice of two or three jobs to accept. All spring there'd be a steady stream of interviewers on campus, and the students would be comparing notes and so forth.

Swent: Did the industry's requirements ever affect your curriculum at all?

Reed: Well, we--at least I--felt a very real responsibility to the industry to try to turn out the kind of engineers that they needed. We would add courses. When I got there, the department had decided that we ought to have a course called mine industrial engineering, basically industrial engineering, but aimed at mining. They had never taught it, so that was the first thing they handed me: "You teach a course in this." I had to get the book and learn all about it myself, one step ahead of the students that semester. That was an example.

I think they had a course in mine safety at one time or another, but there was an awful bind in what you could make required. You might have a course offered, but it was an option. Maybe the mining company would have said that ought to be required, but we had a whole bunch of other stipulations, mostly through the ECPD.

Let me back up. When I went to school here in California, naturally you got all the math, chemistry, physics, and engineering in the first two years, but there was a universitywide requirement for a couple of things. If I remember, it was two courses, A and B (or 101 and 102), in basic economics, and there was one in government--civics, I'd call it, but they called it poli sci [political science]. I think there were two courses in poli sci, and as a matter of fact, I think I took both of them at UCLA to get them out of the way, because there was only pre-engineering there before the war. I had extra time there, and I knew that when I got up here I'd have my hands full.

What I'm trying to say is that in non-technical subjects there was very little required in the overall university curriculum, so an engineer came out with almost nothing but technical training. Shucks, by the time I got into Colorado, the ECPD had started this

drive for the humanities--you know, we were turning out all these animals who couldn't read, write, and whatnot. So there finally was a requirement of about twenty-eight or thirty hours--in other words, almost a full year--of stuff that was non-engineering. Here you were, trying to cram all the engineering into these guys so they could do a good job, and the ECPD were saying, "You've got to teach this, and this, and this," that had nothing to do with engineering. So what do you do? You can't add to the total, so all you can do is take out something technical and stick in one of these humanities. There used to be a lot of joking back and forth about--

Swent: I take it that you didn't think the humanities were really of that much value?

Reed: Well, they are valuable, yes, but I thought they were being substituted in the wrong places, and in one of my speeches that Dr. McLaughlin really applauded (this was in St. Louis) I said, "If you're going to start trying to make better writers--sure, writing was something they needed, and public speaking; you name it, there were lots of things--they ought to be doing that in high school." At the same time they were insisting that we stick it into the four years in college, they were taking it out of the twelve years in public school and giving them basket weaving and all kinds of other things, which didn't make sense to me. I got good composition in high school, and civics, too; I'm sure I did. That was my point in that paper--cram it back into where you've got twelve years into which to fit it, not four years.

But as a result, the fellows that are being turned out now as mining engineers don't have near the underlying good background that we got here--in some things. Now, they're ahead in some places--computer applications and stuff like that--but I think they're much more theoretical, and they aren't as good hands-on engineers. I think I mentioned to you that Weeks and York taught us forging and all kinds of things, and quite a bit of milling from the metallurgists. These things stood me in good stead; I used them. I was trying to teach a little bit of the same thing I learned from Weeks about drill steel, and I was teaching in graduate courses to my students in Colorado. They'd never heard of it! They were all graduate engineers, but--that's what I mean. I think things got readjusted. I didn't agree with all of them, but that was the way it went.

Like I said, I visited practically all the schools. I don't know if I ever went to Alabama, but Socorro, New Mexico, and just about all of them. It was good. It was educational. You knew what you were up against, and maybe you could help them.

Swent: Did you enjoy your teaching?

Reed: I did enjoy the teaching, and that's one of the reasons why I finally quit at the School of Mines after twelve years, because my work got to be more and more administration and less and less teaching. Then there came a drive to--I'm sure the administration had a problem; it's a state-run school, so really they're supposed to be financed by the state. But within the state hierarchy of spending money, they're a small entity, a very specialized one. The big, main university at Boulder, the other one up at Fort Collins, and several more, are all much bigger in population and so forth, so they grab the money; they pull the strings and get the money. We were always fighting, I'm sure, for enough money to keep the school going, and we'd go out looking for support from industry and so on.

At one point, finally, the administration started really pushing sponsored research grants. We'd write proposals to government agencies to get a bunch of funds to support one or two graduate students and some lab equipment. There was always about a 20 percent overhead figure thrown into this. This particular aspect got to us after a while. We had about five members in the department, and if you wrote one of these proposals, you were obligating yourself to have a graduate student studying this. A particular professor was going to be taking more time for that work, so he'd have less time to teach the regular undergraduate courses. The idea with which we went into this was that if we got, say, five of these contracts going, with 20 percent of a faculty member assigned to each one, on paper, then the administration would let us hire another staff member. You know, five times twenty equals 100 percent.

We were working hard at this, and we'd go up to the dean of faculty, or whoever we were answering to, and, no, it was all eaten up in the administration building. So all we were doing was making more work for ourselves and got no benefit. I don't mean individual benefit; we didn't expect to get money personally, but we wanted the department to benefit, and it was all being eaten up over there. So what was the incentive? I flat out told the president of the school, "You've just destroyed all incentive to write these things when you do that." By this time--my wife died in 1969, and it was kind of a traumatic thing.

Swent: You were having a bad time personally, too, weren't you?

Reed: I took a semester off, and Bert Keenan came in. He was an old coal miner, a very good engineer with a background in coal. He had owned his own coal company near Glenwood Springs. Bert came in and pinch hit for me one semester, the fall of 1969. I just took a

complete leave, as I recall. When I came back, he felt that I wanted the job back as head of the department. I said, "Bert, I'm not jealous of the work at all. If you enjoy it, why don't you just carry on as head of the department, and I'll just help you." I was still a full professor. So the two of us kind of--he was head of the department, but we were talking all the time and running it unofficially together.

We both got disgusted with this research situation. As a matter of fact, it got so bad that he resigned, I resigned, and another professor that had been there for years and years resigned, just in protest over this attitude by the administration. That was three professors out of a staff of about five. I don't know if they got the message or not. I don't think it was a healthy attitude, and I still don't think so. I think the primary purpose of a mining engineering department in this country should be turning out well-qualified, first-degree engineers for the industry. Then, sure, do some graduate work, but don't let the tail wag the dog. That's what I think some of them had gone to.

Swent: Most of these research grants you said were not from industry?

Reed: Not very many. Once in a while we'd get something. I wanted more from industry, and I preached that.

Swent: Yes, I know you did.

Reed: They would give grants, sometimes, but I really wanted more close contact. Let them come up with a practical problem that they wanted solved, and we would work to try to solve it. We'd put the student to work studying it, maybe he'd go to work in their mine, maybe he'd do some experimental work, or whatever. I think that's what would really be a big boon to the industry.

Swent: You weren't able to get that going very much?

Reed: As far as I know, no. Oh, there are a few examples. We did some of this with the U.S. Bureau of Mines research branches in rock mechanics and things like that. Some of the fellows--Wilson Blake, whom I took down to Chile for the rock burst problem--that's what he did. In fact, he was a student here [at Berkeley] as an undergraduate, and then we brought him to the School of Mines, and I think he got a master's. Then he went to work for the Bureau of Mines, and he worked on this micro-seismic detection of rock bursts and triangulation and so forth. Finally, as I recall, he was able to use some of his work on a specific mine, perhaps, as his doctoral thesis. He's become a world-renowned authority on rock bursts and that sort of thing. That was a case where he did work

cooperatively with somebody outside the school, but in Bureau of Mines research labs as opposed to a mining industry situation.

Swent: That reminds me that I failed to ask you specifically what your Ph.D. was.

Reed: Here it is. It's called "Mine Opening Stabilization and Stress Redistribution." The master's was more or less this one, "An Analysis of Mine Opening Failure by Means of Models." It was an ongoing thing of the same general subject. You speak of the difficulty of convincing somebody in those days that you could do a Ph.D. The big hangup was coming up with something that was an original contribution, and deep enough. Drilling and blasting patterns--they wouldn't buy that. I had to kind of scratch and figure out--in my application to the graduate school, I had to point out demonstrations of my inventiveness in my past experience.

Swent: Was this still true in 1970?

Reed: I think, to a degree, yes. Because the whole idea of a doctorate is an original contribution to one's field. I think they're pretty rigid about it being original; you can't just further develop something that somebody else has already been working on.

Swent: I'm not sure myself where technology ends and science begins, but there seems to be an underlying argument about this in the mining field. Is it real science, or is it technology?

Reed: Shucks, if your definition of science is physics, chemistry, and math, why, it's all based on that. It's just an extension of that. I wouldn't try to draw that fine a distinction.

Swent: I wondered if this was an issue at the School of Mines, for example, in graduate work.

Reed: Not up through the master's, anyhow. When I was here [at Berkeley], just when I was getting ready to go after the Ph.D., they invented the doctor of engineering. "Oh," they said, "it'll have the same prestige as a Ph.D." In some ways; it was the same number of years, about three, although as I recall a Ph.D. doesn't hold to any particular number of years minimum. But they relaxed, if I recall, the language requirement; maybe it was only one language instead of two. Instead of German and French, they might have accepted Spanish. The thesis was more of a senior engineering report rather than a scientific treatise. I looked at all this and listened to them, and I said to myself, "If I'm going to go through all this, I want to be sure I end up with something that's got the prestige, that's recognized, there's no question about it. If I do

all that work--the work's essentially the same--I don't want a makeshift; I don't want a watered-down degree out of it." So I said, "No, thanks. I don't want a doctorate of engineering."

Swent: So yours was a--

Reed: Ph.D., Doctor of Philosophy in mining engineering. What we gave at Colorado School of Mines was a doctor of science rather than a doctor of philosophy. I'm quite certain of that. So we gave a doctoral, but it didn't have the Ph.D. attached to it. I don't know why.

Swent: But it was science, not engineering?

Reed: That right. It wasn't doctor of engineering; it was doctor of science--D.Sc. This is true, I think, of other engineering schools--not all, but most. I think it might be more true of a mining school, for example, that was not part of a big university. You know, the doctor of philosophy, you've got philosophy departments. I never studied philosophy. You know what I mean. In their academic rankings it fits and is consistent.

Swent: These things get awfully important sometimes, and at the same time seem unimportant to some of the rest of us.

Reed: That's right. Especially in mining engineering, I think, it sounds very academic and esoteric, and maybe a little bit foolish; why worry about such things? But since I felt I was going to be going into teaching eventually, by that time I recognized that in the academic area there was nothing higher than a Ph.D., and that's what I wanted to get.

Swent: You were also able to prove that this extra knowledge helps on the job, too.

Reed: Yes. In fact, I was looking for an opportunity to do that. That's what I had a hard time finding.

Swent: Were you doing consulting at the same time that you were teaching?

Reed: Oh, yes. All the time at the School of Mines. In fact, St. Joe was very good to me. It wasn't a big thing, but during the spring of 1960, while still at St. Joe, they let me help the Corps of Engineers with a problem in Kansas.

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Swent: You were just beginning to talk about your consulting at Colorado.

Reed: I just thought of something else that was kind of a funny little thing. I was hired by Elmer Jones as head mine research engineer, and he was the head of the southeast Missouri division. He was the division manager, like the general manager, but only of those operations of St. Joe. Now, St. Joe also had a big zinc mining area, with entirely different kinds of mines, up in northern New York state at Balmat, and they had the Aguilar Mine in Argentina, South America.

They were having trouble with the beginnings of rock bursts at Balmat. I'd been reading a lot about rock bursts; I did not have any real first-hand experience with them yet, but I'd done a lot of reading about them, and my thesis work was sort of allied to that sort of a problem. I had visions, when I went to work in Missouri, that eventually my training and experience might become known companywide and I'd be asked to help at other mines. Everybody knew who I was; I was introduced to visitors from the New York office as the head of the department at company dinners. I thought that sooner or later there would be an opportunity for me to be called from the New York office to go look at a problem in one of these other mines. They didn't maintain a research department in each property, so I kind of thought that might follow.

Well, it was kind of comical. We had made friends with a young geologist and his wife who had been in South America at Aguilar. They came to Missouri for a year or so, and then they moved up to the Balmat, New York, property. In 1953 I'd been at St. Joe for three years or so, and I took the family on a summer holiday on my own--driving the car, and we camped. We went up to Balmat on vacation, and I thought, "Well, if they had a rock burst up here, I'll take it upon myself--." I didn't do it through the company channels or anything; I just contacted the division manager up there and went in to talk with him and discuss the rock burst with him, thinking I'd offer my assistance if I could be helpful.

Boy, I got the cold shoulder from that guy. There was one who was not receptive, and of course it wasn't up to me to convince him; nobody had told me to convince him. But I thought to myself, "Here's a guy who's got a special problem, and somebody comes along that's at least somewhat prepared to help with it." But I'd never been in their mines, and it was just like I was a stranger. That kind of puzzled me. I don't mean it made me mad or anything; I just thought it was kind of peculiar.

As a matter of fact, when I finally left St. Joe, Dick Bullock took over from me. I told you that he had come to me at the beginning with a new master's degree right out of Rolla. All the time he was working at St. Joe--sometimes in operations, and he was running the department at one point--he completed his doctorate out

of Missouri. So he's Dr. Bullock now. The company made him companywide; he traveled all over the place and did a lot of work out of the New York office. The one thing he insisted on was that he wanted to keep his home base in Missouri--his family and all. He did a lot of traveling; they used him. In other words, they didn't do it with me, but the department did become a companywide research effort eventually.

IX CONSULTANT ON ROCK MECHANICS FROM 1960

The Corps of Engineers in Kansas

Reed: The other thing is that in the spring of 1960, when I was going to be leaving St. Joe in August, the Corps of Engineers was having problems. I had got quite a bit of notoriety about rock bolting by this time, with all these papers and talks. The Corps of Engineers was utilized by several branches of the government. At Atcheson, Kansas, there was an old limestone mine in the river bluff--just tunnels in there, and all these rooms mined out. The government had bought that, and they sealed all the openings up. In effect they air-conditioned or dehumidified this whole big area, and they used it for the storage of specialized machine tools, the sort of things you might use for artillery shells. During the war, for example, the government would go to Remington Arms, or somebody else, and give them a big contract to make ammunition, but the government bought the machine tools and gave them to the contractor to do it with--the big lathes, boring mills, etc. Those tools still belonged to the government.

After the war they didn't want to throw them away or junk them because another war might come along, but God knows when. What they wanted to do was have a place where they could clean them all up, put them in cosmolene--well, mothball them--and put them in a good surrounding. Airplanes and stuff like that are parked out in the Mojave Desert in the dry atmosphere, but for this stuff they thought that old mine would make a good repository. But they had to dehumidify it so the stuff wouldn't rust.

They got in there and were doing some of this and, probably due to the drying out, little bits of the roof would flake off. They wanted somebody to come and consult. I guess they got on the phone and talked to me, to start with. I went and talked to Elmer Jones. We were on good terms, and I could be spared a day or two,

so he let me go. Now, he wouldn't have done that for a mining company, I'm sure, but it was the government that needed something. So I went there.

The other case was at Salina, Kansas. They were digging these big, deep hole silos for missile launching. That was when we were first getting into that. These holes were about thirty feet in diameter and two hundred feet deep in the prairie. It wasn't all good, tight rock down in there; there was all kinds of stuff in the bottom, and they were running into a lot of water washing in and having a heck of a time. We had done some pretty interesting work with grouting to seal off water, so that was another one where I was allowed to go and spend a day or two with the Corps of Engineers people consulting on that, before I ever left St. Joe.

But those were, as I say, exceptions. As soon as I got to the Colorado School of Mines, of course, they almost encouraged a certain amount of industrial consulting that developed your own capability and your experience for your teaching. They looked with disfavor if you abused that, because if you were spending more time consulting than teaching, that wouldn't do.

Swent: That happens, does it?

Reed: Oh, yes, it does happen. Some college professors spend more time out of the office than in the office.

Swent: How do you regulate this?

Reed: We didn't have much trouble with it, I don't think. At least in our department I don't remember anybody abusing it. But I think the administration of any university would just serve warning, maybe. In other countries--I haven't had a lot of experience, but I gather that in Latin America, for example, the professors come on the campus to give an hour's lecture, and then they're gone. They don't maintain an office where the students can come and sit down and talk with them or get counselling. They're high and mighty people who are just brought in from outside. We don't run our schools that way, as far as I know, which is a good thing, but I think this is common in other parts of the world. The university is a place where everybody gets together, but you pretty much study on your own.

Swent: So your consulting was done on vacations?

Reed: Yes, and you don't have a class every day, you know--you have Monday, Wednesday, and Friday, or Tuesday and Thursday, and you may travel over a weekend. With the graduate classes it's pretty much a small group, five or six students, so you can rearrange the

schedule. "We won't meet this Friday; we'll meet two days next week," or something like that. I never felt too much of a problem with it. Once in a while, too, I was perfectly willing to share--if a colleague had a consulting job, I'd take his class. You could arrange that. If you were going to go out, and you had something on your schedule to show a movie that day or have somebody else come in as a visiting professor and talk on his subject, you'd schedule it that day. That way we'd help each other out. That was done on an informal basis. It was all right within our department, and there were only about five people. We tried not to have prima donnas in the department; that would be bad if you did.

Swent: After twelve years there, then you and several others resigned at the same time.

Reed: Yes, and I continued to live in that area for eight more years.

Swent: And you did consulting?

Reed: Yes, I consulted.

Swent: And your engineering business?

Reed: You mean the instruments? That had pretty well folded up by then. That was during the sixties. Soiltest was still doing it, but I was no longer involved with it.

North American Air Defense Command, Colorado

Swent: When did you get in on the NORAD project? What does NORAD stand for?

Reed: NORAD stands for North American Air Defense Command. Early on in the sixties, when the Corps of Engineers was designing the NORAD underground headquarters, I went repeatedly to--

Swent: How did you make the contacts? Through this project in Kansas?

Reed: I think in the beginning, yes. I suppose it was that Atchison job. The Corps of Engineers main engineering offices were in Omaha, so no matter where the job was, the people were out of Omaha. They followed me around; they knew where I was and used me.

Swent: Was that a particularly interesting one?

Reed: Oh, yes. I went there and had big meetings, and we hammered out a lot of details about how the thing ought to be built.

Swent: Did you have anything to do with the site selection, or had they chosen that?

Reed: I think that was pretty much chosen already--the biggest mountain they could find.

Swent: Regardless of what was inside it?

Reed: Right. There was one thing I got out of that, and have gotten since in some of these other large underground openings, and that is that I think probably they should spend more time on testing the site, and most particularly not freeze the design and the orientation of the opening until they really get in there, to maintain flexibility.

The NORAD thing, as I recall, is three big rooms parallel, like halls, with pillars between them, and they're connected by about three crosscuts. In other words, they have a grid there. They ended up with twelve intersections of big rooms. In the first place, I've learned that intersections are the biggest headache and should be minimized. They thought they had located a block of ground that was big enough to excavate this whole complex within solid ground. Well, it turned out a shear zone came through--a weakness--and damned if it didn't just happen to fall right on one of the intersections. That particular intersection is a main control room. All the other rooms are full of back-up equipment. Three-story steel buildings stand in these chambers, mounted on huge railroad springs and three feet from the walls, so if there were a nuclear blast outside, that whole building is on springs and will supposedly keep working.

When we found this circumstance, my first thought was, "Well, why don't you just shuffle these things around and put the control center in the one of the sound intersections?"

"Oh, no way; that's all frozen in the design, and we can't do that." Maybe they were right, I don't know, but the fact is that they found a serious flaw that was unanticipated. It delayed the progress. We had to make that intersection even bigger and line it with eight feet of reinforced concrete, like a great big egg in there. The rest of the chambers are not lined at all--they're just rock bolted, self-supporting--and here's this huge concrete thing in there, all reinforced to beat the dickens. It delayed the whole project about a year. It would have been better if we had done more investigating to start with and been a little more flexible during construction.

Down at Morrow Point Dam near Gunnison, Colorado, there was a big slippage of a couple of intersecting faults or shear zones in one wall of the big underground powerhouse opening, and that started to move in a couple of inches. They had to do a lot of extra bolting with cables to stabilize it. Down in Chile, when I got called back to El Teniente, on an underground crusher station--this was one of the projects in the seventies when I was down there--darned if the same thing didn't happen. They thought they had picked out a piece of ground that was good, with diamond drill holes, but, by golly, when they got in there and were already committed to the whole job, right in the midst of it all was a big *bolon*--sweet potato--they had a funny word in Spanish that they called this thing. It was like a big sweet potato of weak ground, right in the middle of the most critical place. We put in all kinds of extra reinforcing because of that. It would have been better if they had put an exploratory tunnel in and did a little bit more exploration first, and then if need be move over a little bit. It wouldn't make that much difference.

Incidentally, I had a very interesting conversation yesterday afternoon with Tor Brekke, who's here at Cal. He's in civil engineering, but he works especially in underground openings--which is my area, too--and all over the world. We were talking, and that's a point that he brought up. Over in Norway and Sweden, where they've done more of this utilization of underground space, I think, than anywhere else--for everything. He mentioned that this is one of the big things that they have recognized and they apply; they keep things flexible. They design it the way they think it's going to be, but they stay flexible and don't freeze the design until they're darned well in the mountain and have checked the ground all out. Then, if necessary, they'll readjust it a little bit so that they get it into nice, uniform, sound rock. Of course, the bigger the project, the more important this is--the bigger volume it's going to take up.

Rock is a real good construction material if it's sound, but if it's got a fault through it or something else, you better move over or else be prepared to reinforce the fault artificially with rock bolts or gunnite or whatever.

Swent: This has been an expanding field, hasn't it? (No pun intended.) You've gone from mining into underground chambers that have nothing to do with extracting ore.

Reed: Yes. I got interested just by happenstance in surface hydroelectric powerhouses--well, powerhouses, period--in Chile. Then, as I saw the cross fertilization, I got interested in the underground ones, and big tunnels--water tunnels, sewage tunnels,

you name it. The more I got into it, the more I came to the realization that most of the people designing these things were civil engineers with not even geology, much less mining experience. So they really needed and could profitably use some basic mining training. I counselled my students, "You've got a great big future in the heavy construction industry, quite apart from mining to make a buck with lead or zinc." This is true, and the construction companies have come to realize this. They used to come and hire our people; Utah Construction, Dravo, or whatever would come and hire young mining engineers.

But I've seen some examples where they didn't do that, and there were kind of dire results which didn't need to have happened that somebody could have avoided quite easily if they'd understood better about construction in rock.

Portage Mountain Dam, British Columbia

Swent: Do you want to mention any specifically?

Reed: Not especially, I guess. Usually you find people work together pretty well for the good of the cause, but once in a while you find somebody that gives bad advice. I think the real prize was the Portage Mountain Dam in British Columbia--the B.C. Hydro people. That's the government agency that does all the power in British Columbia. They decided to build this huge earth-filled dam on the Peace River, way up in the northeast corner of British Columbia. They started designing it and so forth, and of course they got in a big committee of experts, specialists from all over the world, to help them.

Somewhere along the line, somebody suggested that they put the powerhouse underground, really under the dam, but in the solid rock with the dam piled up on top of it. Now, underground powerhouses have certain advantages and disadvantages. In particular, a place like Boulder Dam--at the bottom of a steep-walled canyon where there's no place to build a powerhouse. There, they're hung in the air between the canyon walls over the water. That would have been an ideal place for an underground powerhouse, but they weren't even thought of in those days, I guess--well, not much, anyhow.

But up in a big, broad, flat valley, there is all kinds of space, and it's easy to build a concrete and steel powerhouse at the toe of the dam and let the water come in there in their big penstocks, and you don't have a problem. But somebody got the idea that it was the thing to do--the mode--at that point to build

underground powerhouses; they had nice big ones in the Snowy Mountains and so forth. So somebody brought this idea up. I'm sure that some of the experts that had built all kinds of underground powerhouses in Norway, Scotland, and so forth, in good solid rock, where they were a good choice, advised them that it wasn't a good idea. But there was one man responsible in B.C. Hydro, and he had this big committee of experts under him to offer advice, and then somebody else would make decisions about what to do.

There was a young geologist up there who was a new employee and a protegé of a senior geologist who's done some remarkable work in Canada, very well thought of all over western Canada and, I guess, even in the East. They had this senior man retained, but he had a young fellow that he had hired to understudy him and so forth, and the young fellow did most of the talking--was allowed to do a lot of talking. He really went way out of line with the idea of this underground powerhouse, and when they'd get into the committees and writing the letters of recommendation and so forth, he would literally pooh-pooh the opinions of these senior fellows with real experience from other places. I'm saying that the top man should have put him in his place. "You're the geologist; interpret the rock for us, and the engineers will handle design." But this guy had little if any underground experience; at least he'd never worked in mining much.

The worst part of all was that this rock under the dam had a coal mine in it; it was weak shale and sandstone and stuff that nobody in his right mind would try to open a great big opening in. It just wasn't the right kind of rock for a big opening for whatever purpose.

Swent: Was it good enough to support the dam?

Reed: Well, the dam simply sat on it.

Swent: And that was all right?

Reed: Well, yes. You could grout it and so forth. The hills on both sides were the same rock, but you could make a big earth-filled dam. It wasn't the same as a concrete arch dam that has to have real strong abutments; all you have to do is make sure the water doesn't leak. I don't think there was anything wrong with that part of it.

But nobody in his right mind should ever have decided in the first place to make an underground powerhouse there. There was no physical reason for it, and it was the wrong kind of rock--the worst possible kind of rock. Yet, this darned geologist kept

insisting, and when anybody who knew better would point it out, he'd talk--shoot off his mouth, is what I'd say--and the general project coordinator above him, who should have known better, wouldn't shut him up. So they compared it to rock bolting in a coal mine three feet high and things like that. This was going to be an opening about eighty feet wide and over a hundred feet high, and a thousand feet long in this stuff, and it wouldn't hold anything.

They designed it to be all bolted, as it was opened. You open one of these things with a tunnel right along on the center of what's going to be the arch of the roof, then you widen that to the full width, and then you bench it down. So you bolt it as you do it. As soon as they got the full width opened up and the great big arch, and mined a haunch in each side of the arch into the wall, then they went in and built a concrete arch roof sitting on those two haunches--all this before they benched.

In good rock, they've learned in Australia in those powerhouses, you're better off to leave no haunches and just bolt the rock together. Because the haunch just makes the span greater; it's a notch in the wall about fifteen feet. So instead of a seventy-foot opening, you ended up, really, as far as the rock is concerned, opening up something that was about eighty feet wide, and still in this horrible ground. A big consortium of Morrison-Knudsen and five other construction companies took on the job. It happened that Morrison-Knudsen was the operator, but the other five put up a lot of the money, equipment, and people.

When they started this job they had a certain amount of rock bolts specified. Of course, if the people on the job saw that the ground was weak and were afraid of it, they could put in more bolts than the minimum specified, and an additional payment was scheduled for the extra bolts. They started measuring how much this great arch would sag, as they started at one end, and when they'd gone about six or seven--

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Reed: I'm getting into an awful lot of details here, is this all right?

Swent: That's all right. Were you in on this yourself?

Reed: Yes, I got called in as a consultant in the lawsuit. That's what I'm getting at. I went up there at the requst of Morrison-Knudsen. The lawsuit is why I got into it. Poor old Morrison-Knudsen is up there digging this gosh-awful hole in the ground and complaining bitterly all the time about, "We shouldn't have ever been in here in the first place." Well, I don't know if they actually said

that, but it became obvious pretty soon. They were bolting as they needed to, and they were managing. The sag that they were measuring in the roof--actually opening in the roof above their heads in the layers--was less than an inch and fairly uniform. They were progressing, and presumably that's what they could count on. Then it would stabilize, and they'd get the bolts in.

After opening about six hundred feet of arch with a uniform measured roof sag of less than an inch, suddenly for about two hundred feet the sag increased drastically. It got to as much as five and three-quarter inches of separation of the layers over your head within twenty feet of roof thickness. The instrument was a bolt that was anchored up there twenty feet and hanging free in the hole, and then they would measure to a reference point on the immediate roof. When that changed, it could be nothing but opening in the rock between the surface and this anchor point up there twenty feet. In the first place, twenty feet wasn't long enough in an opening seventy or eighty feet wide. They should have been anchored up there a hundred feet as their reference point. At only twenty feet above the roof the anchor point, the reference point, was likely to be moving down as well. What you measured might be only part of what was coming down, so it was even worse than it appeared.

They'd gone along, and it was less than an inch and had seemed to stabilize. All of a sudden it started to go bad, and the rock was breaking up--all kinds of things. I would have said it had failed right then: get out of there. But it got up to five and three-quarter inches, and this darned young geologist was still insisting everything was perfectly okay. In effect, M-K put in--I can't remember how many extra twenty-foot bolts. And, by golly, after it was all over B.C. Hydro wouldn't pay them for the extra bolts. They said they weren't necessary, that they put them in just to get paid for them.

They finally got it all in. I wouldn't have stayed in there working, and I wouldn't have kept men in there. But when it was all over, they were submitting the bill, and B.C. Hydro wouldn't pay it. So they filed a lawsuit. That wasn't the only thing. There were all kinds of overruns on the job. It became the biggest civil legal suit in the history of all Canadian law. They started off suing for about $30 million. It wasn't a jury trial; a judge and two engineering aides sat there and listened to all this, and the aides would interpret to the judge the engineering stuff. It went on for a long time, from about 1969 to 1971.

The legal beavers had submitted their primary claim for about $30 million, and then they had a bunch more based on bad faith or whatever of B.C. Hydro that took it up over $50 million. They were

only allowed to file the $30 million claim first, until the judge heard a little about it, and then he would rule. Well, he only listened for a few weeks, and then he said, "Go ahead and file the works." Boy, the end result was a really castigating big document, and they won hands down. B.C. Hydro was made to look like--and made to pay up.

I'm saying that this was a real example where--usually people work to good advantage together and try to get things done, but I would blame a big chunk of it on that one particular man who mismanaged his team of design consultants.

Swent: What was your role in this?

Reed: When they got into the lawsuit, the project engineer in Vancouver, who was an American Morrison-Knudsen employee, got on the phone looking for somebody to help him on rock bolts and rock mechanics. So I started going up there, and I worked for a long, long time with the lawyers before the thing went actually into court. I was educating the lawyers and reading vast quantities of letters. This is where the details came out about the young geologist, because some of those letters were really damning. He was shooting off his mouth about something he had no business talking about. He's supposed to interpret geology, not design things. He wasn't an engineer; he was a geologist.

Scarcity of Geological Engineers

Reed: That's another pet peeve of mine, incidentally. Every state in the country, I think, has at least one and probably several departments of geology. That's fine; teach people geology--I call that letters and science geology. But a geological engineer is something quite different. He's an engineer first and a geologist second, literally, and he gets the same basic training as any other engineer. There are only about sixteen accredited geological engineering departments in the country. They're as scarce as mining engineering departments.

So what you have running around the country are an awful lot of people who are, quite literally, geologists, but only a handful of them are geological engineers. A lot of them realize this and will give good geological advice. They may even absorb, with time, some experience in the engineering application of that advice on construction projects and so forth, but unfortunately there are a lot of them who don't have any real engineering knowledge at all, and they overextend themselves. They think that because they have

a degree and so forth that they ought to--I don't know if I'm making myself clear. I like geology myself, and there are a lot of good geologists. I've known good ones of both ilks, but sometimes they can get out of their depth and they don't know it. I think that becomes a problem. Before anybody starts working on one of these jobs, I always ask if he has a degree in geological engineering, or is he a letters and science geologist, and then what his experience is.

Swent: There's also engineering geology.

Reed: That, I think, is often an effort on the part of one of these letters and science geologists to imply that he studied, or his experience and so forth, was in engineering geology. But a guy who's an engineering geologist is not an engineer under the skin; he doesn't have a full engineering educational grounding. If he has that, he has a degree in engineering. I wouldn't be surprised right here; even on this campus there's a big gap--always has been, and I understand there still is--between those who are in the geology department and geophysics, and the applied geology in the mining department and in civil engineering. They had a mining geology option in the mining department early on, and economics came in there somehow or other. I know there was always a kind of a gap here between people like Ed Wisser, basically a mining geologist, and those in the geology department. Wisser didn't want to lecture in the geology department here; he wanted to lecture in the mining department. He taught the application of geology to finding ore and developing mines.

The geology department here--and I'd better be careful what I say--somehow seemed to feel it was beneath the science or beneath them to make a practical commercial application of geology.

Swent: Turns it from an art to a craft?

Reed: Or turns a science to a craft. I ran into this a little bit when I was here. I was trying to teach in the mining department and study, too. But I talked to some of the people who were concerned with earthquakes. This was a very advanced group.

Swent: That's where the engineering geology is coming in now.

Reed: Right. I don't know what's come along, but at the time I was talking to some of those people about using geophysics in a practical sense for finding ore bodies and things. Nobody was doing that here. I was asking about a cross-breeding or cross-fertilization between the geophysics department here and the seismology people and ore bodies. They weren't interested. That's the kind of an attitude I mean that I don't admire.

Swent: Of course, that's become a big thing now.

Reed: Yes, and at Colorado School of Mines there was a whole department in geophysics with real crackerjacks; they liked to talk about earthquakes, too, but they were finding oil and ore bodies and all kinds of things. They were using geophysics for a practical commercial purpose, and I think the folks here would think that was demeaning or something. That was the impression I got, and I gather even now that it's still somewhat that way.

Swent: Maybe the commercial aspect is what taints it.

Reed: I don't know. It's a little bit like the Sierra Club. But there were people over there in geology who were crackerjack mining geologists. Carlton Hulin was one, and he was certainly out consulting. My brother George, after he'd graduated from here and was running mines, used to have Hulin come to look at his mine and give him help. So there were people in that department who were very much the other way, but I think department policy was more generally idealistic.

It goes along with what I said about a geological engineering department. The first two years are exactly the same; it's math, chemistry, physics, engineering statics and dynamics, and all that stuff. The average geologist doesn't get that. So if he goes out to be the geologist on a tunneling scheme or something, it's fine; he can interpret the geology. But does he know about the strength of the different rocks? I like to say that maybe that kind of geologist is very involved and learned, and I admire his knowledge about how the rocks were deposited and the sex life of the little beasties that made the coral reefs, but the question is: where does this tie down to being something useful? If he can absorb that and translate it, fine. In a case like the ore bodies in Missouri, indeed, it was that high-falutin geology that finally figured out where to drill to find those algae reefs that had the lead in them. It was that very scientific geologist who figured that out, but he was working in a mining company department and contributing that knowledge, really, in an engineering way. You wouldn't call that fellow an engineer. He's a geologist who knows where to use his geology to best advantage.

Some geologists seem so esoteric. It's like mathematics.

The Importance of Applied Mathematics

Reed: Did I speak about mathematicians teaching mathematics?

Swent: No, you didn't.

Reed: I've got a pet peeve about that, too. I don't think engineers should be taught mathematics by mathematicians. They should be taught by engineers who have learned the mathematics so well on the application--and this is a rare breed, I might say; I'm certainly not one. True mathematicians are so enamored of their art, and most people I don't think can even visualize mathematics. I know I can't. But they can, so they talk wonderfully in abstracts--you know, calculus and all this. But an engineer has to do word problems. He has real problems, and he has to learn how to use the calculus to solve them.

I was good in arithmetic, algebra, geometry, and trigonometry. But, boy, when I got into calculus it began to get beyond me. I think it was mostly that--that you were getting it from graduate students in mathematics in the advanced courses, and they didn't teach you a lot about how to use it. When it gets beyond you, it's hard to visualize in the abstract. I managed to get through. I think the only "D" I got in my whole college career was in calculus, and when I came back as a graduate student they insisted upon putting one year of advanced mathematics into my program, which is understandable. Boy, I really sweat getting through that. I spent more time, I think, in the prof's office down here after class than I did in class. But I managed to get through.

Swent: Did you need it later?

Reed: No. I was going to say that I never once in my whole career have ever specifically used calculus to solve a problem from scratch. I used the formulas that are derived through calculus, and I understood the derivations in advanced stress analysis, where that calculus was used. I waded through all that in the classroom, and I learned how the formula was evolved or developed, but then I ended up using the formulas; I never went back to the calculus.

It's comical--when Professor York had a stroke in recent years, I would go to visit him. He lost his power of speech and everything. He was with his daughter sometimes, and it was real rough on her. She is good in mathematics and computer applications and lives in Santa Barbara. Her husband, John, is a super theoretical physicist with a doctor's degree. He got Lou Gehrig's disease and lost his power of speech also and is in a wheelchair, but he can still hit the keyboard on a computer. He was in

research, the head of a department down there--a big research outfit--and they kept him working from home with his computer for quite a while.

They have three grown sons, one out of college, one in college, and one in high school, and they're bumping up against calculus. Their mother, Susan, has been helping them, and maybe their father, too. To get to the story, when I got down one day on a visit, we were sitting around the living room talking about this sort of thing with the boys. The father, since he can't talk, has his keyboard in his lap and a little computer screen. He'll join in the conversation; you hear "click, click, click," and there's his comment to the conversation. I was trying to tell these boys not to be too upset, to wade through it. I said that in my whole career I had never really used the calculus. I managed to get through it, but I never actually used it. Then I hear "click, click, click," and John says, "Me either." Here's a guy, a top-level theoretical physicist, who hasn't really used his calculus either.

Another example of this: there was a metallurgy prof at Colorado School of Mines, Jack Lubahn, a real good physical metallurgist. He had learned his mathematics thoroughly from an engineer at MIT, I think. He could use it, and he did use it. One of the biggest contributions he made at Colorado--he was in the metallurgy department, but he went over and taught basic mathematics in the math department. That's where I really got this idea of mine, talking it over with him and explaining my own situation and so forth. I think it was really his idea, because he was an example of a really good engineer who knew the math, and he learned it from another engineer who used it and taught it well.

Swent: They teach it better, then?

Reed: Yes, I think so, because they teach it from an engineer's point of view and show the engineer how to use it. It's not abstract, up in the air. I was talking this over with somebody just recently, and they said that a mathematician will recognize a person who can visualize mathematics as a rare breed, and I believe it. My youngest daughter was always very good with numbers, and I think she still is. That's right, she was telling me. She's the one up in Portland. She eventually finished school and got a degree in languages. She said she was in her senior year in languages, practically ready to get her degree, and she took some math course. She did very, very well; she got almost a perfect score. The math prof gave out all the papers and scores, and then he said to my daughter, "I want to see you after class."

She thought, "Gee, what did I do? I got the good grade, but maybe he thinks I cheated or something."

After class he said, "Come down to my office." They go trudging off down the hall, and he still hasn't said anything. She's worrying all this time, wondering what in the world she's done. He gets her down in the office, sits her down, and says, "I've looked into your background."

Then she thought, "Oh, my God, now what?"

He says, "You're studying languages. You ought to be a major in math. You've got one of these three-dimensional minds for math," and tried to talk her into changing.

She says, "I'm ready to graduate in languages. I can't change my whole career now." But there was a math prof who recognized--like I say, miners learn to think in three dimensions in space, but mathematicians do it in theory, I guess, and only a few people are gifted that way.

The Manhattan Underground Aqueduct

Swent: Were there any other of your consulting jobs that you particularly wanted to mention? Were any of them particularly interesting?

Reed: One I might mention is the water aqueduct under Manhattan. The whole city of New York, on Manhattan Island, is supplied from water upstate by a single old tunnel built in 1917, and they can't shut it down to inspect it because there is no parallel system; so it has become really critical. A sudden collapse or other failure in that old tunnel would be a real disaster. To correct this situation, an "emergency project" was begun in 1970. A new auxiliary parallel tunnel was driven down 250-800 feet deep in the good, sound rock; it's metamorphic gneiss atanding on end. The tunnel is 13.7 miles long and 27 feet in diameter, which reduces to 24 feet when concrete lined. Of course, there were a lot of pump stations and shafts, so there were a lot of different contractors working on it. You go down in a shaft several hundred feet, and then you go off in a tunnel both ways. Then there'd be another shaft over there, and maybe some other contractor is going both ways from that one.

It was obviously very good rock, so the specifications called for rock bolting. However, they always put in contingency items so that if they run into a real bad fault zone or something like that,

they can stand steel sets. They scheduled piece-work prices for any steel sets--big eight- or ten-inch H-beam things, curved to fit this basically horseshoe-shaped tunnel.

So they all start working in 1970. I don't know if you're at all familiar with the labor conditions in New York City, but it's just awful, apparently. The unions run everything and jack everything up, and costs go out of sight. These contractors got started, and they were driving right along. They were driving tunnel, but they saw that they were losing money the whole time. And this rock was real good. By golly, they noticed that if they would claim that they had bad conditions and start standing steel sets, the price per set was so great that they would literally make more money standing sets than driving tunnel, and that was a way to recoup their position.

This is where I blame the city engineers' supervisory crews. They should have stopped them right there and said, "This is solid rock; there's no need for steel sets. Go ahead and bolt and get it over with."

Swent: This was in the twenties?

Reed: No, in the seventies. By about 1977, the entire tunnel had been driven, all the sections connected, and the concrete lining was beginning. I got called by the city in August 1977 to come and help them in a lawsuit. The contractors were suing the city because they wouldn't pay them for the steel sets. They claimed there was bad ground, and they had to stand sets because of safety conditions. There was a lot of money involved--millions of dollars--because you rode along on the train for miles and saw these solid steel sets, all with lagging, cribbing, and blocking behind them. Incidently, all that timber should be removed before concreting, at still more expense.

So they called me in. I went and had a look, rode on the train through the entire tunnel, and I didn't see <u>any sign</u> of bad ground at all. If it was really bad ground, then there should have been weight on the sets. The blocking should be showing compression, the sets pushed out of line, and all kinds of evidence that the rock was moving or doing something. I couldn't see any sign whatsoever, and besides, just looking at the rock, it was perfectly sound rock. It's not the kind of rock that goes bad.

They had used the rock bolts, but another claim was that the reason they couldn't continue to use the rock bolts was because the rock was so bad that they couldn't get anchorage. Remember I told you all about the anchor--the expansion shell bolt. They said, "We can't use the rock bolts because they'll pull out, and they're not

safe." I said, "Tell me another one. That rock's hard and should give excellent anchorage." This was something I'd done a lot of--rock bolt pull testing. The proof of the pudding is that you put a hydraulic jack on the bolt. You install the bolt, or even when it's already installed, and you get hold of the end of the bolt with a hydraulic ram. You just pump it up and pull until the bolt either breaks or it slips and pulls out by the roots, expansion shell and all. People at the Bureau of Mines said that you pull only enough for a small displacement, and you measure very accurately the give. Some of it's the stretch in the bolt; the bolt will elastically stretch. But if it's a little bit more than that, then you say it's slipping. By their standards, once it slips a little bit they stop pulling altogether; they say that's the end of the test.

Well, I had my own ideas. In Missouri I said, "We're going to test, and we're going to pull them out by the roots, or snap them, and we'll find out which expansion shells hold." Incidentally, when I was doing that experimental work with bolts at St. Joe, we were doing pull tests all the time. We found that some expansion shells would not hold in our rock; they would eventually slide out. Then I went to a different manufacturer with a different kind of expansion shell, and I could never get one of those to pull out; I broke the bolt. It's pretty exciting when you pull a three-quarter-inch high-strength bolt in two. It goes "Clang," and the end comes flying out of the hole like a javelin. It's kind of convincing. [laughter]

I'd been doing this routinely for a long time in Missouri. Indeed, when I went in with Soiltest, one of the things in their rock mechanics sections that I helped them put together was pull-testing kits. We'd sell a packet of all the paraphernalia it took to make these kind of pull tests.

Back to New York, I said what we needed was to go along where all these bolts were in already, even between the sets. You see, they had it all bolted, and then they put the sets up. So I said, "Go back, and we'll pull the bolts out."

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Reed: I had done a lot of bolt pull testing to check the anchorage and the strength of the bolts at the lead mines in Missouri and had been preaching it at Colorado. When I went to New York and they showed me this thing, I said, "The first thing to do is prove to them beyond any question--demonstrate, document--the fact that those bolts are holding very well, always would, always will, and so forth, and there was no need for the sets to start with.

I got one of my ex-students, who was eager to learn a little bit of consulting. His name is Jerry Zink (he lives in Durango, Colorado now). Jerry went back, and he stayed on the ground for several weeks or a month. What he did was just go through that whole darned tunnel--miles of tunnel--and on a spot check basis, every hundred yards or something, they would take one of these bolts that had already been in there for a long time. What you do is unscrew the nut, thereby releasing the tension, and you put an adaptor thing in there that you can get hold of with the hydraulic jack and the ram, and then you put the nut back on. It's a collar. Then he'd pull the bolt. He used to laugh at me; I'd say, "Pull it out by the roots, Jerry," so he'd always quote me on that. It doesn't sound very scientific, but that's what we were doing.

He pulled about 145 bolts, and only 4 showed unacceptable anchorage. He broke nearly every one. I had said, "Don't just pull them until they slide or something else; either you pull it out by the roots or it breaks." When he had all this data, then I went back on one visit, and we sat down across the table in what they call discovery with the attorneys from the other side and the city's attorneys. We just presented this material and said, "This proves--." And they couldn't dispute it, it was so darned obvious, so they just gave up that claim altogether. That's where we certainly saved the city some money in one aspect.

But that whole project was just a great ongoing disaster for the city of New York. Started in 1970 as an "emergency project," they do not have that tunnel working yet, in 1991!

Swent: This was to be a backup tunnel?

Reed: Yes, this was a replacement so they could go back into the old tunnel to inspect and repair. They've had some falls in it, they're pretty sure, but they can't go in there to see. In 1978 its hydraulic capacity was reported to have dropped by 13 percent. If anything really goes wrong with that old tunnel, the whole city's going to be out of water, period.

Swent: So this is an auxiliary tunnel?

Reed: Yes, this is a parallel tunnel with cross links and so forth, so that if and when they get it working they can bypass bad sections and make repairs. When they started in 1970 they were all very aware that they were facing an uncertain catastrophe situation, and they were trying to highball the project to get this new tunnel for that reason. They have run out of funds repeatedly. The whole thing has cost several times more than they thought it would, and it was only half done when they first ran out of funds. They couldn't get new appropriations. They only had a little funding,

so they'd work this year on a little bit of this and a little bit of that. First they lined it all with concrete; that had to be done. Then they had to make the pump stations and valve chambers every once in a while for the distribution pipe system to the city. New York City could really develop into a disaster if they have a major problem in that old tunnel; they wouldn't have any water.

That was kind of an interesting one where the consulting really paid off for that client.

Swent: Of course, after you broke all the bolts off they aren't doing any good, are they?

Reed: Oh, but that's just a few bolts among thousands. We only spot checked at random. We sampled the thing from one end to the other so they couldn't say, "Oh, well, that was good ground where you tested, but we were over here." We even went where the steel sets were standing and pulled the bolts right out from between the sets, and they were perfectly all right.

We also needed to check the sets for loading, but Jerry was a young fellow and didn't have the experience of working in heavy ground. Well, I did, but I couldn't scramble around those sets. What I wanted somebody to do was go along, really, in those long stands of sets and check for details like the blocking--the wooden blocks and wedges--where the sets are blocked to the ground, because that's where you see the signs of rock movement coming on, biting the wedges and squeezing the blocks and things like that. Physically, I couldn't do that, but that's what I wanted somebody with credibility to do.

So I got Sam Shaw, who had been an instructor at the School of Mines and doing graduate work. He's back in Colorado now, consulting and so on. He had a lot of experience in a lot of different mines, so we got him in there towards the end. He went along and verified what I had been able to do from the train. There was no sign of any weight ever coming on those sets. They were just standing there.

Swent: Decoration.

Reed: That's all they were. Actually, all the wood behind them had to be stripped out before they concreted. The sets themselves could stay in the concrete; that's all right. But all that extra business was just extra expense that the sets cost, and they wanted to get paid a great huge amount of money for standing them. I don't know what ever happened to the contractors. They must have gone broke, but that wasn't our fault. That was a combination of a lot of things.

I've heard this is true of anything you do in New York City--it costs three times what it does anywhere else because of the labor unions and politics. They've got a grip on everything. I haven't had that much experience; that's the only case, but it certainly was obvious to me there.

Swent: You haven't mentioned any underground crusher stations.

Reed: There was one at Tennessee Copper that I went to see for a New York engineering firm. As a result of that, the same firm called me when I had to make that quick trip to Chile in 1970. It was actually Cerro de Pasco that was opening up what they then called the Rio Blanco Mine, and what's called the Andina Mine now. They put not only their crusher station underground, but they mined out chambers for the whole mill because of the snowslides. They just decided that their mountain was so steep and bare that if they built anything on the outside it would get carried away. So they mined out chambers, and they had the flotation cells and everything else in big underground rooms.

That was a case where they got the crusher station half developed, and one side of it started sliding in along some slips and fault planes. I got this call from New York in June of 1970. My oldest son was getting married the next weekend, and I had a meeting that I had to be to that Saturday. They called me from New York on the Sunday before and said, "We want you to go to Chile to look at this crusher station."

I said, "That's great. I'd like to go back to Chile." I'd never been back to Chile, you know. "When shall we set a date for it? The following week after the wedding?"

"Oh, no, you've got to go right now. It's an emergency."

How in the world was I going to go to Chile and back and examine anything, all between now and next Saturday? As a result, I think I flew out Monday, got to Santiago on Tuesday, and they took me right up to the mine. I was up there two nights, I think, and they took me back to Santiago, stuck me on a plane, and I was back in the States. I never got to look around one iota. I wanted to go over to Braden and refresh my memories and so forth.

Swent: They wouldn't wait a week?

Reed: The mine people thought it was so urgent. I don't think it made that much difference, when I got there and found out what it was all about. I don't think my counsel made that much difference. But they wouldn't wait, and I couldn't change the wedding date, so I had to come back.

One thing I might mention. You've probably had experience with inflation in Latin America.

Swent: Oh, sure.

Reed: But you talk to your kids up here who haven't experienced that, and they don't understand that inflation is not prices going up; it's the value of money going down. When I went to Chile, the exchange was thirty pesos to the dollar, roughly. By the time I left, six years later, it was about a hundred pesos to the dollar. During that time, a thousand pesos was called an escudo. You didn't even carry escudos; they were like thousand dollar bills. We did all our business in five, ten, twenty, and hundred peso bills. Oh, if you were going on a long trip, you might get one escudo and carry it along as a reserve, but you didn't deal in escudos; they were too big.

By the time I went back in 1970, they no longer dealt in pesos. You talked in escudos, just like you used to talk in pesos. I mean, a meal was a bunch of escudos. I had an hour or two in Santiago before plane time when I wanted to go out and buy my kids some curios in the shops. I got out there, and I could not assimilate this. The prices of things--I didn't know what I was dealing in. Maybe I was suffering from jet lag or something, but I just could not. I bought two or three little trinkets, but the prices of things were so outlandish in my memory terms that I couldn't picture it.

And do you know that right after that they went through another thousand multiplication, and they began dealing in the "new" peso, which was a thousand escudos. So by the next time I went back, in 1975, with my wife, and all the rest of the time I was down there, there was no problem because, really, I was dealing in the same numbers that I had twenty-five years before, but it was multiplied by a million. Now the exchange is about three hundred of those "new" pesos to the dollar. So we're talking a multiplication factor of something over three million.

For example, there was a kind of a social security in Chile. They called it the *fondo de retiro* and gave everybody a pension. It was deducted, just like social security is here from our paychecks. When I left down there, after you were out of Chile for a year you could apply and get back the part that you had contributed, which I did. But it happened that my father-in-law had been there about thirty years, and they had huge *fondo de retiro* credit. Some people would buy real estate or something else with the funds. I don't think he did any of that; he probably should have. I don't remember when this would have been, but long after my wife died, Mr. Butler died up here in the States.

Somebody in the executor business approached me--I guess it was the lawyers--for advice on how to apply--maybe he still had some credit coming in his *fondo de retiro* in Chile. There was some question about it. At that point Chile had gone through all this inflation. I don't know if I gave good advice or not, because maybe they made some arrangement for that; I don't know, but I doubt it. But I sort of think that great big retirement fund would have been worth nothing, or not worth going after. That was my suggestion to the lawyers. Maybe it was bad; I don't know.

Swent: It was probably millions of something that wasn't worth anything.

Reed: Right, just not worth anything. Anyhow, that made me a real believer in inflation. When I saw inflation here of 10 percent or so a few years ago, I took it seriously. I still believe you're better to invest your money in the stock market or real estate--something real, anyhow, something that goes up with inflation. Don't stick it in a bank and just get interest on it.

Swent: It was in Peru and Bolivia where I saw it. It was a terrible shock to me to see some little trinket that cost several thousand of something.

Reed: Yes, and you know that only amounts to two dollars or something.

Swent: They'd have these price cards in the shops, and there'd be a little sweater that was seven thousand. You realize how awful it is for money to be so devalued.

Reed: Yes, it just kind of leaves you in shock. The same thing even in Mexico. We traveled in Mexico a lot.

Swent: I haven't been to Mexico since that terrible inflation.

Reed: Even the first stages of it were pretty shocking. We'd go through re-evaluations and such. If you went down there at the right time, boy, you had your vacation for almost nothing. Then another time it was almost as expensive as up here, and what you really felt for was the Mexicans. They were still getting paid in pesos; they didn't have the benefit of any exchange.

Swent: And the people who are on retirement--that's where it hits.

Reed: A fixed income, yes. You really feel sorry for them.

Developing Warning Systems for Mines

Reed: You asked me one time about warning systems in the mines, and we didn't say anything about that.

Swent: We didn't talk about split sets, either.

Reed: Oh, okay. On the subject of warning systems, when the fire happened down there [at Braden], the only way to get a warning in was the telephone--and only where the telephone went, and that was the main offices, the *bodegas*, and perhaps a few shops. But for practical purposes, for most of the men it was the three or four offices of the production levels, and then it was up to them to go out and run down all the men. Of course, some of them were pretty easily found, but some were way out and maybe never did get a warning and either walked back and died in the smoke or walked back until they got some smoke in their face and had sense enough to turn around and go back, like I described to you, and sit it out.

One of the first things that Stan Jarrett did when he got down there was to start developing multiple systems of warning. There was quite an electric lighting system, wired in, in the main drifts of the mine and in the offices and *bodegas*. One of the things they did was fix a rotating little drum, about eight inches in diameter and a foot and a half long, with electrical contacts on it and a little motor to drive it. If you wanted to send out a warning to anywhere the electric lights went in the mine, this thing would blink the lights three times, hesitate, and then three times more, and then three times more. In other words, that's the international emergency signal to get your attention. Then it would blink the signal that would be for that level ringing in the cage--you know, going up and down in the cage in a mine. Now, we didn't all know those signals, but the cage tenders did. But in a general way it would tell you what level the fire was on. That was all it was trying to do: there was a fire, get out, and where the fire was. That was one system.

I think maybe they developed more telephone hookups, and maybe more flexible ones, because, like I said, the smoke actually shut down the main telephone exchange early on, so even the telephones we had went out of action pretty quick.

The other system, which I think was fairly common in other mines, and it had never been done at this mine, was a stench warning system.

Swent: That's one of the things that you marketed later on.

Reed: Yes. That's kind of a comical tale, which I'll describe. My brother and I got a patent on it, and I didn't think we deserved a patent.

Something called ethyl mercaptan is a product that we got from Monsanto. It's similar to an alcohol but contains sulphur. It's the most powerful, evil-smelling substance that you can imagine. I've heard it described in a lot of different ways; rotten cabbage is one that I could never quite [agree with]. It'a a stink that you would never confuse with anything else. Other things, like oil of eucalyptus, have been used. Well, there are cough drops that smell that way, you know.

Swent: That's a nice smell.

Reed: Yes, that wouldn't startle you. But this stuff, boy, you don't need a second invitation to get out if you smell it. It's extremely powerful. In that huge mine, with miles and miles of pipe lines and tunnels and all the rest, how do you get it in to the men quick? You can't just put it in the ventilating air, because that travels too slowly. But the compressed air in the compressed air lines travels fairly quickly, and especially it goes to anybody who's working with compressed air--the guys out on the end of things in the development drifts and the miners and so forth. If they're using compressed air, it's going to get to them.

So clear back at the compressor station is where they would have injected it in those days. Going into the main air line, which was probably a twelve-inch line, they have this little injection mechanism. If they put in a little over a liter--twelve hundred c.c.'s in that one specific great big mine, they would inject that into the compressed air going into the mine. We had fire drills after that, and we had people all over the mine in obscure places, and we'd synchronize our watches and then note when we got the scent. I believe that got everywhere within something like ten minutes. It was pretty startling how quickly and universally that reached. Of course, the minute it came out into the air stream, then it also got carried at a slower rate on beyond there. I always thought that was a pretty good success.

Swent: It didn't damage people?

Reed: Oh, no, it wasn't toxic. And besides, you only got a tiny whiff of it; by the time it came out the other end it was very much diluted. But, boy, that stuff is potent.

I don't think we knew this at the time, but there is one hazard about it. Up in Peru, in Cerro de Pasco, they had a situation where they had one of these set-ups. The compressor

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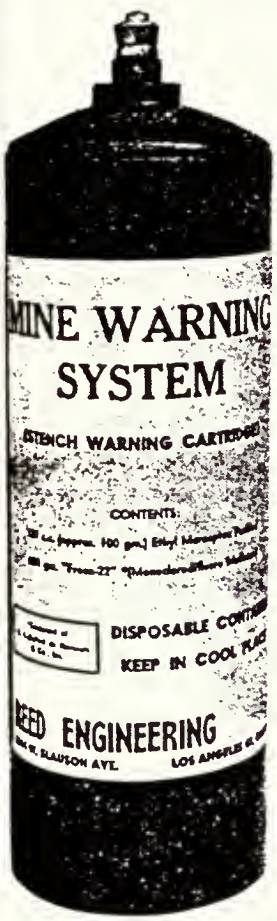

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house was on the surface, and six-inch air line went from the compressor house over to a portal and into the mine. Somewhere in there, I think at the end of that six-inch line, but before it went in the mine, there was a receiver--a big tank, which is like a surge capacity in a compressed air system.

They decided they'd have a fire drill one time, and they dumped I don't know how much; it would have been much less than a liter, because it was a small mine. They squirted it in back at the compressor station. A compressor normally puts out hot air; when you compress air, it heats up. But if the compressor has a leaky exhaust valve--every time the piston comes up and compresses the air and the valve opens and lets that compressed air into the line, when the piston goes back to get another load that valve is supposed to close tight. Well, if that valve gets leaky, some of the air that the piston just squeezed out and that got hot, gets back in and is still hot and gets reheated. That keeps going, until eventually the compressor will blow up; it overheats. If it's kind of on the way to that, there may be hot carbon particles, just like out of an engine--it's like dieseling or something, so the compressor becomes a diesel engine, you could say.

Anyhow, there are these hot particles of carbon that go into the compressed air stream. This ethyl mercaptan is highly volatile, highly explosive. It's about like ether. You know how careful they are around an operating room; everybody wears slippers. I guess there have been some horrendous explosions in operating rooms. Well, this is like you were squirting a bunch of ether into *compressed* air, which contains a lot more oxygen--seven times as much oxygen per volume--as the outside air.

The result of all this was that they put this stuff in, and all of a sudden, with no warning, it exploded in the pipeline. Six hundred feet of pipeline and the big receiver at the other end blew up--exploded, split. I don't think anybody was hurt, because it wasn't underground, fortunately. But it made it very obvious that you had to do something about this possibility, because if you had a real fire in the mine and wanted to advise the people underground, that wouldn't be the time for a secondary explosion problem.

When I got up here in Berkeley and was doing all my reading about explosions and everything else, I was visiting, as I said, the Bureau of Mines safety research station over here in the mining building. Sometime in that few years that I was here--

Swent: [sneezes]

Reed: Salud.

Swent: Gracias.

Reed: --I found a couple of papers. The Bureau of Mines was asked to come down to Peru and write an analysis of what made this accident happen. That was one paper, and somewhere I have copies of those papers. It's like an information circular for the Bureau of Mines. Then they wrote another one. They started a research project in the lab to find out how to counteract this explosion hazard. The first one was an analysis of the accident, and the second one was what to do about it.

Their final conclusion--it was all spelled out--was that if you injected enough of some inert gas into the pipeline--the compressed air line--along with the mercaptan, you would render it non-explosive. They even came to the conclusion that one of the simplest gases would be Freon, which is what you use in your refrigerator or your air conditioner. They made tests at varying amounts, and the final conclusion was that if you put six times by weight of Freon in at the same time as the ethyl mercaptan--in other words, if you put a hundred grams of ethyl mercaptan and six hundred grams of Freon in together, the mix is non-explosive.

Anyway, when I read all this, I thought to myself, "That's fine. They've got it all figured out, but who in the world is going to go buy Freon and ethyl mercaptan and figure out how to get it into the pipeline and all the rest of it? That's a lot of messy business. What you need is a product off the shelf that a mine could order, and it would do it all for them in a kit." We didn't invent the idea. Like I say, it was all in this USBM publication.

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Reed: The final thing we did was to get standard little cylinders, like a Burnsomatic cylinder that you'd use on a camp stove with propane in it, so we didn't have to design a special cylinder; there were people already making those. We got that cylinder, and we could squeeze into it that particular batch that I mentioned, which was a hundred grams of one and six hundred grams of the other. It was a sealed cylinder, so once it was in there it didn't smell or anything; it wasn't stinky to handle or store. Then we sold it with a little piece of copper tubing and a couple of fittings so they could just stick it up on top of their compressor line, and by turning it upside down the pressure of the Freon made it self-injecting. You see, you have to get it in against the pressure of the compressed air that's in the line trying to come out. You have to exceed the pressure of the compressed air in order to make it go in. Well, it happens that Freon at normal temperature is about 120 psi, and the airline is 100 psi, so that's fine; it was no problem.

What we could sell to any mine was this little cylinder as a package stench warning system. The design that we went to--of course, every mine would require a different amount to be reasonable. We thought we'd start with a module of one cylinder, which would do for a relatively small mine. We had rules of thumb, which they also gave, I'm sure, in the Bureau of Mines publication. But rather than try to stock and have these things ready in a jillion different sizes for any mine, or to make them up to order, we just would say, "This mine uses one cylinder; this mine we'd manifold and use three cylinders." You know, the whole batch would go in--that would be their dose--but they could do that for themselves.

So we went into the business. It was not without its humor or problems. When my brother got the first five-gallon bucket of ethyl mercaptan from St. Louis--of course, it was all sealed up carefully and essentially didn't smell until he opened it, but then it drove him out of the shop. He finally got the filling operation organized with an outfit in Los Angeles. Filling cylinders with Freon takes special equipment, so we went to people that were filling aerosol cans and all kinds of things. We were bad news when we came around, because you didn't want to get this mercaptan mixed up with somebody's underarm deodorant. So they charged us kind of through the nose, and we'd have to get a minimum order of a hundred cylinders done each time.

The upshot of it all was that we were selling these cylinders. Somewhere along the line my brother said, "Shouldn't we get a patent on this?"

I said, "Bill, how can you patent something that's been published by the government already--all the details? All we did was put it into a packaged commercial form, but the details--." But I'll be darned if he didn't get a patent on it, so we've got a patent on something that I don't think was patentable in the first place, not that we ever used the patent; it didn't make any difference.

The other thing about this was that at the time there was no U.S. mine regulation, certainly no federal one, and I don't believe any state one, that required a warning system in a mine. A few years later there was, but at the time there wasn't. It was funny that we sold very few in the United States, but we sold quite a lot in Canada, where there was a law, and our biggest orders went to Broken Hill, I think it was, in Australia. We'd send about twenty five units at a time--big orders--through the New York importing

office, I remember that. Ultimately there was a requirement in this country. Anyhow, that was kind of interesting.

Swent: Are you still doing it?

Reed: No. Eventually it sort of petered out. It was a lot of nuisance, and we didn't make a lot of money at it. Finally, the other company, whose business was filling cylinders, started doing it on their own, using our idea, and selling them directly and not giving us any payment. In other words, they jumped our idea and started doing it for themselves. They had jacked up the price they wanted to do it for us, and then we forgot about it, so they went ahead and did it. I don't know if they're still doing it or not, but they were for quite a few years.

That's another one of these things. Is it worth paying a lawyer a bunch to--there wasn't enough involved, so I didn't worry about it. That's one of the patents that--I've come to the general philosophy that on small things, if you've got a good idea, go ahead and make it, build it, and sell it until somebody else can do it cheaper, and then pick up a new idea. [laughter] Patents, in my experience--and this isn't always true, of course; I mean, you might patent a better mousetrap and be a millionaire. But with these things, there wasn't enough sale of them to be worth worrying about. Really, you paid five or six hundred dollars then to get a patent, and God knows how much you'd pay in legal fees defending against competitors, so it just didn't seem to be worthwhile.

Underground Sites for Detecting Neutrinos

Swent: We're continuing now after a break. I think you'd better tell us about getting into the neutrino business.

Reed: You were looking in my notes of the South African visit, and that's what triggered it all. It must have been at least two to three years prior to 1967, when I went to South Africa. A physics professor, F. Reines, contacted me from somewhere in the East; I think it was Case Institute in Ohio. He explained to me that a neutrino is a real high energy, active cosmic particle that penetrates maybe even the whole earth, but certainly penetrates anything, essentially. But they're very rare, and the rest of the atmosphere is full of millions and millions of other particles that are much more common. So when you try to make a detector for neutrinos, the problem is that you may detect a neutrino, but you've got to weed him out of jillions of other spots on the film or whatever it is that you track those particles on.

This guy had the idea that if he could get deep underground, he would filter out all these other particles; they couldn't get there if he put up his detector deep underground. Well, he wasn't a miner, and he didn't think much of going down into the earth. Maybe he had claustrophobia. The reason he called me--well, we were a well known mining school, to start with--was that we were at the face of the Rockies, right in Golden or Denver. You've got that great big mountain face.

Swent: You were pretty high up in the atmosphere already.

Reed: That's true, yes. He thought maybe we'd find a tunnel somewhere--an adit, in other words--in some of the old mines--or new mines, as far as that goes; he didn't care--that went way back into the mountain. What he was looking for was to get about a mile of earth over his detection site.

He ultimately came to Colorado, and in the meantime I'd done some research. I got in the car with him, and we drove up, I think, to Climax; we went different places. I remember specifically there's an old mine tunnel, and I can't remember the name of it now, but if you go up the canyon from Golden, you come to Idaho Springs and then Georgetown, and above that is Silver Plume. At Silver Plume there was still standing open this very long tunnel. Oh, it was at least two thousand feet long, and maybe longer, back under the mountain, an old silver mining tunnel. The main thing is that it was still open; it was abandoned but still open. You could walk in there if you got permission. I'm sure it had a gate on it.

We went up there and walked way back in there. When it came right down to it--we think of a horizontal adit going in and developing an awful lot of cover over it, but mountains aren't really as steep on average as we like to think they are. It's not like a vertical wall.

After spending the whole day with this guy and walking the tunnels and only getting maybe two thousand feet of mountain over the top of us, I told him, "If you really want to get down deep, the thing to do is to go down a shaft. Don't go in on a tunnel; go to some really deep mines." I said, "The very first thing up in Canada, you can get at least six thousand feet vertical; that's over a mile. The deepest mines in the world are in India and South Africa. Approach them. For a variety of reasons, the language and a few other things, I recommend South Africa. In the first place, they'll speak English there, and they're very advanced technically, scientifically, and all the rest of it." I don't know anything about India, but the Kolar goldfields there are the other extremely

deep mines in the world. I was looking for ten thousand feet or deeper.

I said, "You need to approach the people in South Africa, and I think they'll be very interested and cooperative." So off he went. He said, "I'll do that." That, I think, was the last I heard of the man. I got down to South Africa myself several years later, and when I visited that particular mine, they said, "This is what we want to show you--the mining problems and all--but we've got another special surprise for you." That picture there [points] is a physics professor from the University of Witwatersrand, who became the counterpart of the physicist professor from the States. He was in charge of this neutrino laboratory.

Swent: Case-Wits Laboratory, East Rand Proprietary Mines. Is that the one?

Reed: That's the one, yes. That's the professor who showed me around, but he's a South African professor, the counterpart of the guy I had steered there three or four years before. By the time I got there, the station was all up and going, and they'd been catching neutrinos. They were all so interested.

Swent: There is the one at the Homestake Mine in Lead.

Reed: I thought this one in South Africa was the first in the world. More recently they have gone ahead with one in Canada, because they have deep mines in Ontario. I've read about the one in Homestake. Do you know what date that would have been?

Swent: It's been there since the fifties, I think.

Reed: That would have been before this guy came to see me, then. And it's down deep, down five thousand feet or so?

Swent: Yes. Homestake's down to eight thousand feet now, but it wasn't down eight then.

Reed: I'd be interested to know when that went in, because to my knowledge, the one in South Africa would have been the first. By 1967 they would have been announcing their results in their scientific literature, and right away somebody up here would have said, "Hey, we want to do that, too."

Swent: I believe it's the government that's doing it in Lead.

Reed: It could be the nuclear people, or atomic energy.

Swent: They don't really talk a great deal about it, so I think it may be confidential. Or maybe it's just that it's so myaterious that nobody understands it.

Reed: I didn't understand it. They had things like big aquariums, as I recall it (there may be aome pictures), and I think they had them full of heavy water or something like that. When one of these neutrinos would finally get down there and zap into that water, it left a streak. I don't know if it was radioactive or fluorescent or what the heck it was, and that's what they got a picture of. And that's all. I mean, this thing sat there for days, weeks, months, and then all of a sudden, twang, they'd get one. They had only caught, I think, seven, they told me, in several years.

Swent: But they proved they existed.

Reed: They proved they existed. The station they had made was kind of a makeshift first approach. They wanted to find out if it was going to work--if it was worthwhile making it more sophisticated. They had, indeed, proved that to themselves and whoever was financing all this, and they were in the midst of making a real elaborate new one when I was there.

Swent: You were there in 1967?

Reed: Yes. Until you've visited those mines, it's unbelievable how hot and miserable it is down there. They're like no mines I was ever in anywhere. This kind of stuff with fancy electronic equipment had to be dehumidified and air-conditioned, and that's not easy when you're down there in the midst of rock and the whole environment is about 130 degrees temperature. So they've got a real problem. Of course, to work or anything--it's a real experience to go see what they're up against.

Swent: Why were you there? Why did you go?

Reed: I'm sure it was Neville Cook who was behind it.

Swent: He was with the Chamber of Mines there. Had you met him?

Reed: Yes, he had come to see me. He reminded me the other day that he was up here on some kind of a tour, and he came into my office in Golden in 1962 the first time. I think it was Charles Fairhurst, who has been head of the mining department at the University of Minnesota for many, many years--I think he may still be--who wanted to go on a sabbatical, so he asked Neville to come up and replace him for either one semester or one year. So Neville was in Minnesota, I think he said, in 1964, and then he did the same thing again in about 1968. Between the 1962 visit with me and 1964, he

and I probably rubbed elbows at some symposium or something. They may well have had a meeting at Minneapolis that I went to.

Anyhow, he got the idea, and he may have instigated it with the Chamber of Mines--they were getting ready to set him up with a mining research laboratory in the Chamber of Mines for all the gold mines in South Africa. In the process, he was concerned about getting help, advice, and counsel from people who were doing that kind of work in other places in the world. So I think he proposed to the Chamber of Mines that they invite foreign experts, one at a time, to come down there at their expense and spend enough time to study their problems and make suggestions. He mentioned the other night that Professor Potts from the University of Newcastle in England was down there, and offhand I can't tell you for sure of anybody else.

Observing Mines and Advising in South Africa

Reed: What I got was an invitation to come down in 1967, at their expense, for about three weeks, study their mines, and discuss what I saw with their supervisory people and so forth. I thought it was a marvelous opportunity, because I had been reading about South Africa for years and wanted to go there and visit. To get an opportunity to go at their expense and be shown around, I really welcomed it. I knew that in the whole world, they were head and shoulders deeper than anybody else, and they had great problems with heat, ventilation, rock bursts--you name it, they had it. And they were very advanced in their solution of these problems.

Indeed, I had been using their solutions. I had written them, and they had helped me a great deal with the grouting problems in Missouri. I think we'd have lost our shaft if I hadn't had the benefit of a couple of good letters and some papers to read that told me how to grout under very high pressure underground and not get back flooded, and that came from South Africa. So I knew their technology was way ahead, and that we needed to know more about it.

They ended up sending me to Russia. I think I told you about that.

Swent: The Russian trip was at about the same time. That was the International World Mining Congress.

Reed: Right, I think it was the fifth; Roman numeral V strikes me.

Swent: Yes, you talked about that.

Reed: I got to ring it in on their first-class air ticket, if you recall, so it didn't cost me anything to go to Russia on the front end of this trip to South Africa. That was just a happy coincidence.

In South Africa they set me up in a hotel downtown, and they'd tell me, "Tomorrow morning So-and-So"--whom I'd never heard of, of course--"will be around at six o'clock," or six-thirty, seven, depending on how far we had to go to the mine--a given time, anyhow. I'd get up in time, get my breakfast, and go down and be waiting. Somebody would drive up, one or two people, and off we'd go to some mine. We might drive fifteen minutes, or we might drive two hours. Once we even flew to an outlying district--I think they called it the Orange Free State or something like that--quite a ways out and stayed a couple of nights. It was several hundred miles away.

The main thing is that they would take me to a different mine each morning. As soon as we'd get to the mine, we'd go in to meet the general manager on the surface. I've got to tell a little story here. South Africans are the darnedest tea drinkers I ever saw. Mind you, I like tea and always have, but they drink tea like we drink coffee. When you go anywhere here, people offer you a mug of coffee. Well, they do it with tea, only more so. You get to the mine and go in to the general manager, and immediately you have some tea and discuss the thing with him. He maybe tells you what he hopes you're going to see. That's all the gracious part of it.

From there you go to the change house. While you're getting into your white overalls to go underground, you got some more tea. Then you go to the shaft, and they're all very deep, so you go way down in the bowels of the earth, and they keep you busy all morning. Down underground it's hot as the dickens, and you're down to your underwear and a white coverall. There's no such thing as dressing warmly; you're trying to get rid of your clothes. As soon as you get underground you commence to sweat. You're not doing anything, just standing there talking, and you're drenched. You can see in the photos that the suits we're wearing are soaking wet.

This goes on for two or three hours, and they take you to show you one thing or another. The one thing they do change underground is that now if you get thirsty you get a glass of semi-ice cold lime water. That's pretty good, too. Eventually they would bring you up, about noontime, and you have a chance to take a shower and put your street clothes back on.

Then they'd take you to the staff dining room and offer you a drink--whiskey or whatever. I always took beer. I knew they had good beer, and beer always treats me pretty good, so I experimented

with their beer. I joked that I was an informer for Coors. Mostly they'd give me real light beer. They'd think of the lightest beer they could, like American beer. I remember one time, after several days, they asked me one day, and I said, "I've been drinking that. Now give me what you think is a good beer--dark beer or something." Boy, they brought me one that was like a real dark ale. You almost had to chew it. It was good, but it was certainly a different category.

We'd have a drink, and then we'd have a nice lunch. Then all the young operating engineers and the management--there'd be twenty or thirty technical people there--and I might give a little talk to start with, maybe on rock mechanics, maybe show some slides. Pretty soon it would revert to questions and answers. Like I say, usually each mine had one or two special problems that they had shown me, and I would be able to give my impressions of those, and maybe possible solutions. They would ask questions, and then they might bring up other subjects.

I remember in the area of rock mechanics in particular, I felt that they had not carried rock bolting to its ultimate potential. In particular, around their shaft stations they might bolt a little bit, but then they'd pour some concrete in front of the wall, as if it were a support. I remember explaining that I really didn't think that was helping the situation because--I don't think I've talked about this.

When you shoot off a piece of dynamite, buried in the rock, it puts out a compressive wave that goes out in all directions. It usually doesn't exceed the strength of the rock in compression, so it doesn't really break anything until it reaches the free face with the air. Then it can't transmit its energy into the air, so it gets reflected. It's like that drill steel; it's the same phenomenon. What you get is a wave reflected back into the rock, that bounces off the surface and goes back in, but it's converted to a tensile wave instead of a compression wave. If it builds up to the tensile strength of the rock, which is only about 10 percent of the compressive strength of the rock, then a slab of rock flies off; it's detached and thrown off violently. In other words, the breaking of the rock from a blast really proceeds from the outside in, even though the shot was inside.

I drew an analogy for them about their rock bursts, because I was very interested in the rock bursts. A rock burst--the failure of the rock deep in the earth somewhere--is like a dynamite blast going off. There's a whale of a lot of energy, and it sends out a compressive wave. What really does them in is when that wave hits the wall of a drift or the shaft, and the whole wall of the drift or the shaft flies off. It tends to choke the drift--this is

explosive, mind you--with broken rock and busted sets and everything.

So their biggest problem is protecting their people when something like this happens. Of course, if somebody's right in there, he just gets clobbered; there's no saving him. But the fact is that this may happen in a drift, for example, with a lot of people back inside somewhere. The people may be all right, but they can't get out. Also, the air is shut off; the drift is full. It's not just a question of an hour or two to get in there; it may be days before they can get back in there. So keeping the drift open, even in a damaged form, is very important.

What I was trying to tell them was that what little experience I'd had with rock bursts--which is very minor compared to theirs, but at least some--in a deep shaft in Missouri, we found that if we bolted the wall very well and fenced with chain-link fence, like cyclone fence, under the washers of the bolts, we had a little burst and it would shake it all up and loosen it, and the wall would move out maybe six inches or a foot, but nothing flew. What you ended up with was a restrained mass of crushed rock.

A Rock Burst in Missouri##

Reed: I had only a little bit of personal experience [with rock bursts] in Missouri, but I think it was pretty valuable. Actually, what I learned there was kind of interesting, too. I told you that most of the lead mines in Missouri were all in sedimentary dolomites.

Swent: I was just thinking that it was entirely different rock.

Reed: Yes, and we didn't have rock bursts there. But while the St. Joe geology department, under Dr. John Brown, was going all over the Ozarks looking for lead mines, they did geophysical surveys to try to find the ore. There were no surface indications in some of these areas. The ore was down about eight or nine hundred feet, so there were no outcrops to study or anything like that. They used different schemes, and one of the things they did was gravimetric surveys and so forth to find out what that old Precambrian erosion surface looked like, which was igneous rock. When they'd find a high in that, even though it was down there a thousand feet, it was an old hump in this surface, and that would have been an island in the sea that came along later with the limestone forming. Did we talk about that--the atoll and all that kind of business?

Swent: Yes.

Reed: In doing all these things, they were looking for lead, but they were using gravimetric surveys, and somewhere along the line I guess they used a magnetic survey. Maybe those lumps sticking up had a little magnetite in them; there was an anomaly or something. But all of a sudden in one place they got a tremendous anomaly. Something was really, radically magnetic--not just a little bit, but a whole lot. They started doing some wildcat kind of drilling, is what it was. Sure enough, they got down there about twelve hundred feet. They went through all the dolomites, and then the bottom of it was a very permeable sandstone for a hundred feet or so, and then into this Precambrian.

They were drilling down there, and all they were getting was this porphyry, just hard, pink porphyry--not a thing in it. They drilled another hole like that, way down--imagine, these holes have to be costing a lot of money at this point; maybe three thousand feet deep they were drilling. They'd never drilled in that Precambrian before. Anytime they hid the Precambrian, they said, "We're wasting our time; the lead's above that." But they were looking for something new, they didn't know what. About the third hole they ran into massive, pure magnetite. Magnetite is about 65 percent iron; it's one of the richest ores for iron. I guess we ordinarily mine ore that's 40 or 50 percent iron.

They did some more drilling, and they found a huge, massive lens of pure iron ore--pure iron oxide--about five hundred feet thick and three thousand feet long, and the holes bottomed in it at three thousand feet. They said, "Gee, this is worth mining, but we don't know anything about iron mining." So they made a deal with Bethlehem Steel, a partnership, and they took on the operations to get the shafts down into it. Bethlehem finally took over the production.

Anyhow, here we were sinking two eighteen-foot diameter shafts through all this stuff and down to twenty-six hundred feet or so. That's where we got involved in the grouting and the high pressures, because we had water at 350 psi in that sandstone, and you couldn't grout it with any ordinary cement grout; it was a perfect filter. They gave us the problem long before they got to it, and I started writing South Africa for advice. American Cyanamid Company finally came up a new product they were just developing, a polymer chemical grout. This stuff you pumped in, supposedly in a true solution form so you could pump it through anything--a filter or whatever. You put with it in the solution an activator, which made it change from a monomer to a polymer, plus a retarder which delayed the reaction just long enough to let you get it into the rock.

As a monomer it was like a true solution, but when it became a polymer it jelled, just like Knox gelatin, except of course at room temperature. The timing was the important thing, so the amount of retarder that you put in this stuff was critical. You figured out how long it was going to take you to mix it and pump it and get it in place in the rock where you wanted it to turn to gelatin, and you figured backwards from there. Cyanamid had never tried it underground. In fact, I don't think they had tried it much anywhere, really; they didn't have much experience with it. But it certainly sounded like what we had figured out we had to have.

Swent: Did you mix this stuff with something else?

Reed: No, just water. It came in drums, a granular solid. You dissolved it in water, and when you had a clear water solution, then you could pump it into the sandstone. We usually figured it would take us maybe ten minutes to get it in place, so we'd allow twenty minutes; we'd put retarder in it for twenty minutes to give us a little leeway. Then you'd pump a certain amount in there, and then you'd stop pumping so you wouldn't have it migrating all around and let that set up. Actually, we'd do one hole on one side of the shaft, then we'd do a hole on the other side, and then we'd come back.

It worked. There were some details--which are written up, incidentally, in that list of references. Lee Bilheimer, from our mine research department, did this work and did a great job of it.

That was just one problem, the grouting problem. When we did get down into the andesite, where the magnetite ore was, they had brought a fellow down from the deep gold mines in Porcupine District, a Canadian, Doug Bent. They have rock bursts up there--you know, in the Lakeshore Mine and the Hollinger Mine and places like that. They were working down five to eight thousand feet in quartz. That's the kind of rock where you get rock bursts. So they'd hired him, and he was down there to help with this deep mining, which was a whole different kind of mining from the lead mining in dolomite. Of course, we didn't anticipate rock bursts, but it was a happy coincidence that he'd had a little experience with such things.

We were sinking this shaft, down sixteen hundred feet and in the porphyry, Precambrian, and just opening up a shaft station. We hadn't opened up hardly any ground at all. All of a sudden the darned wall blew up in their face. Fortunately, I don't think anybody was hurt that first time, but it scared the dickens out of everybody, of course. None of the locals had any such experience. If it hadn't been for Doug Bent, I don't think they would have gotten anybody to go down that shaft again. But he took a few men

down, and what they did was put up chain link mesh. They were just driving a little exploration drift in, and they'd drive one round, and then they'd put the mesh up overhead and bolt it before drilling the next round.

It was a local place, I think, where there was something crazy going on to multiply the stresses. We didn't ever have very much trouble, but enough to really get everybody's attention. I saw the behavior of this wire mesh, and it saved a couple--one time there were two guys standing there talking when the roof right over their heads burst. The mesh came down; it loosened a couple of bolts and the mesh bagged down, but the rest held. They probably went down on their knees and were scared to death, but they would have been killed or badly hurt without the mesh, and they weren't touched.

Swent: Your measuring device wouldn't catch that, because it happens so suddenly?

Reed: Yes. This doesn't give any gradual warning movement, and that's the reason it bursts, because it can't move gradually and relieve itself. It's like glass. Have you ever seen people testing a piece of concrete in a testing machine?

Swent: No.

Reed: Well, a testing machine is just a big hydraulic jack, is what it amounts to. You make a test cylinder of concrete, say six inches diameter by twelve inches high, and put it in there--after it's cured, of course--and you squeeze it until it breaks, and then you say, "That concrete has a compressive strength of 2,500 psi," or whatever. Even those cylinders are pretty violent sometimes when they break; pieces fly around, but they don't really explode. They tend to break a little bit and then break some more. But if you took, for example, a big cylinder of glass and put it in a testing machine, it would be unbelievably strong; it would be much stronger than concrete. But when it did go, it would just explode like there was a stick of dynamite in it, and you'd have glass fragments all over the room.

That's what the serious rock bursts are like. It only happens in a very strong, brittle rock. It stores up a lot of elastic deformation energy and then lets go all at once. That's the hazard.

In South Africa maybe I was helpful in getting them to think more of, "Never mind putting up this concrete and everything else," because I think that's just ammunition; that's just going to fly off. That's like a weak rock surface; it's not stuck to the rock, so if the energy of one of these waves comes out and hits that,

it's just ammunition to throw across the shaft or the station or whatever. I read now in the South African mining literature, and they're pretty well converted over to grouted rebar, like I came up with, and they've gone to grouted cable. They use a woven steel cable and grout it in the hole. It has a certain amount of give, you know, but it still hangs on. They put mesh in front of it so that now, I think, when they have a rock burst--as far as the access tunnels go, they are damaged but usually stay open and let people in.

Developing Grouted Rebar Bolts

Swent: You have not mentioned your development of grouted bolts. You talked about bolts, but you haven't mentioned the grouting of the bolts.

Reed: That came along as a kind of a happenstance or serendipity. This was at Norad when we were mining that awkward intersection that we spoke of. The standard rock bolt specified there was like a deformed, hollow bar. It looked like a one-inch rebar, but it had a hole through the center like a drill steel would have. The idea was that they could be grouted easily and made a permanent fixture in the rock. You went through, and as you developed you put in these bolts and anchored them with their expansion shell at the back and a plate on the front. At a later stage they would come along and pump grout through a little plastic tube that was under the roof plate and into the bottom of the hole alongside the rebar bolt. They'd hook on with their grout pump, when they wanted to grout the rebar, and they'd pump cement grout--slurry grout--in through that little tube, and of course it would fill the hole from the bottom up. But all the time it was pumping grout up the hole around the outside of the bolt, the air had to get out. That's what the hole in the bolt was for. So the air was coming back out the center of the bolt, and when you finally got the entire twenty feet of hole full of grout, you'd get a little squirt out through the hole in the bolt, and you knew you'd got there with the grout at the end. Then the bolt was grouted, and presumably it was a permanent thing and bonded to the rock.

Okay, when we got into that real bad intersection, they were having a heck of a time. Even the bolts weren't all holding, the rock was so broken up and so forth, and it was a big intersection. So somebody came in with a new idea from Sweden, called a Perfobolt. This amounted to a little sheet metal tube, really, four feet long, that was about an inch and a half in diameter. It was split lengthwise; it really came to you as two half tubes, a

half circle four feet long, and it was punched full of quarter-inch holes, like a colander in your kitchen.

It was a way of getting grout in the hole easily without a pump. You laid two of these half pipes on a bench, and you had a bunch of mortar mixed up to a consistency like you would use to lay bricks, and a trowel. You just buttered these two half-circle pipes level full of mortar. Then you'd put the two of them face to face, and now you had a pipe with a lot of holes in it, full of mortar, and you'd put a twist of wire around each to hold it. Now you had a slug four feet long. If your hole was twenty feet deep, you made five of those. You pushed one up the hole and followed it with another, and a third and a fourth, until you had five of them. The entire hole, in other words, was full of these tubes, one after another.

There was a little space outside of the tubes, obviously; they had to go up the hole. Then what you did was stick a rebar--a reinforcing steel--in the center of the tube at the bottom and drive it up there, usually with a jackhammer or an airleg. You'd push it up the middle of the tube, and that displaced the mortar out through all these holes. Everything had to be the right relationship in size, but what you ended up with was a hole in the rock completely full of good mortar, with a rebar in the middle of it--no tension in the rebar, just passive. What you were doing was making a reinforced rock structure analogous to an ordinary reinforced concrete structure. You were giving the rock mass tensile strength, which it did not have. And, of course, if it had a lot of fractures, blocky ground, jointed ground and all, you were in effect tying that all together with that rebar.

Swent: You did away with the bolting mechanism entirely?

Reed: Well, there was no tension. It was doing the same thing in one respect. It was doing the same thing as a grouted bolt did. But we had always put a lot of emphasis and reliance on the fact that an ordinary tensioned bolt was like prestressed concrete; it was putting active tension or compression back on the rock. We made a lot of getting all the tension you could get into that bolt, because that related to compression in the rock and so forth. So when they came along with these things, we said, "Gee, that's <u>passive</u>. It isn't going to do anything until the rock tries to move. It isn't doing anything ahead of time; there's no pre-stressing aspect to this." So we kind of pooh-poohed it. We thought, "Well, it's worth a try, but it can't possibly be as effective as where we're tensioning these regular bolts and <u>actively</u> clamping the rock together."

Well in the first place, the Perfobolts held. The rock stopped loosening up where we used them. That was convincing. We didn't understand why, but they did it. Then in that intersection, like I told you, they finally concluded that they were going to have to reinforce it with eight feet of concrete. Well, it had broken oversize, all right, but not eight feet, so to make *desquinche* (enlargement) we had to mine away anywhere from one or two feet to maybe eight feet more rock to make room for the concrete, and we were already working in a huge opening that had us scared to death. So it was a ticklish business.

We started doing it a little at a time, but this is where the Perfobolt showed up well. When we'd come to a place we had to enlarge, that had already been bolted with the regular bolts, the bolts were easy. You just took the nut off the end of them and pulled them out or burned them out with a torch. As soon as you loosened them, they weren't doing anything anymore. You blasted the rock out from between them, and, fine, cut them off with a cutting torch and went ahead. But, jiminy, we had a hard time with those Perfobolts. When we had to take them out, they were so good at reinforcing the rock that we couldn't take the rock out. You see what I mean? They were really showing their capability of holding broken rock together. You couldn't blast them out.

We went ahead and got the job done, but all the time we were all casting about for an explanation of this behavior.

Swent: The Swedes had just discovered that it worked, but they hadn't done any research on the theory?

Reed: Apparently not. There was no explanation of the theory of the effectiveness. Did I give you the article about my return to Chile and the grouted rebar?

Swent: Yes, I have it.

Reed: Well, attached to it is a reprinted article, "Grouted Bolts for Faster Rock Stabilization." I sat down and worked out--it's simple math--an analytical explanation for why. It goes like this: A bonded bar, continuously bonded to the rock, will reinforce the rock much more effectively than a bolt which is only anchored at the ends and tensioned, even though the bonded bar starts off with no tension at all. That was hard to understand. We thought the tensioned bolt was active, and we thought the bonded bar was very passive--inactive. We couldn't understand why it was so effective.

It turns out--let's assume that the rock is trying to loosen up, and a crack opened up in there, somewhere within the length of

the bolt. If you've got a ten-foot bolt that's anchored only on both ends, and a one-eighth-inch crack tries to open somewhere in the middle of it, the rock, in effect, stretches the entire ten-foot bolt by an eighth of an inch, because the bolt elongates uniformly. Even though the bolt is already under some tension to start with, lengthening it an eighth of an inch increases the tension some but not all that much. In effect, it's like a stiff rubber band; it's capable of stretching quite a bit.

But if you compare that with what happens when you have a bonded bar, even though it starts from zero tension in the bar, if you start opening that crack up, the whole bar doesn't stretch an eighth of an inch; but rather, zero length of bar does. What's right at the crack is the only part of the bar that is being stretched. The rest of the bar is just up in the rock, anchoring it. When you try to stretch zero length of steel bar an eighth of an inch, the stress goes up tremendously, and fast. That stress in the bar, of course, is clamping reaction on the rock, which inhibits loosening.

I think this explained why a simple grouted rebar works so well. About the same time (1969), Dave Ortlepp, whom I'd met in South Africa in 1967, sent me a paper about the use of a yieldable rock bolt that he had developed down there. Because sometimes when a rock burst comes through, even though you've bolted the rock, the rock bolt gets such an awfully sharp, sudden load that it can't yield fast enough, and it pops. He was trying to make a rock bolt that would have a built-in yieldability so it would continue to hold the mesh and the rock during a burst. Even though it "stretched" a foot, it wouldn't break, so the shattered rock would be contained.

I thought his paper was so good that it ought to be in our literature, because I know that most miners in this country and Canada don't see South African literature. I thought I would take it to an SME [Society of Mining Engineers] meeting and combine my idea with mostly his idea--I mean about his yieldable bolts--and I'd add this business about why a grouted rebar works to the same paper, and I'd present it. Then I got it printed in the [Colorado School of] Mines magazine for March 1970. [see illustration]

Swent: Don't they also grout the regular rock bolt that is anchored and tensioned?

Reed: Mostly no, because that grouting is kind of a messy, expensive secondary operation. Most of the rock bolts--the tensioned bolts--are in coal mines and places like that in extraction openings, which only have a limited life span. It's not a permanent thing, and they don't worry about them rusting out, losing their tension,

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routed Bolts For Faster Rock Stabilization*

*John J. Reed***

outed vs. Ungrouted Rock Bolts Rock Stabilization

ully grouted rock bolts have been used and specified some years in construction projects for two primary sons. They enhance permanency against corrosion, l loss of anchorage. However, grouting has usually n done long after rock excavation and stabilization is cluded in order to simplify the bolting procedure l eliminate the effects of nearby blasting on freshly uted bolts. Therefore, the effects of fully grouted bolts early rock stabilization after rock excavation have not n noted generally. In those cases where fully grouted its have been installed early, however, even as tensioned dowels, they have been observed to be markably effective in stabilizing the rock mass and venting displacement of individual blocks and frag-nts. The calculations which follow show why this ould be so.

lt Action in a Moving Rock Mass

When an excavation is made in solid rock, the walls d roof move inward until they either stabilize or col-se. This movement is a combination of elastic motion, hich must occur, and is largely simultaneous with cavation; and block and fragmental relaxation and adjustment, which involves dilation of the mass and acks within it. This latter action takes time, but under itical conditions, if uninhibited, will result in collapse of e rock mass. The sooner and more positively this block laxation is arrested the more of the inherent strength of e rock which remains, and the higher the probability at permanent stability will be achieved and collapse oided. The action of a fully grouted bolt is much more sitive and rapid than that of an ungrouted one in eventing rock dilation and shifting. A tensioned, but ngrouted bolt invariably loses tension due to creep and bsequent blasting, and is usually retightened several mes before being finally grouted. All this permits rock ilation with time.

Let us examine the situation when a joint perpendicular a 10-foot bolt opens 0.1 inch somewhere within the olt's length. With an ungrouted bolt, the extra 0.1 inch f strain will be distributed uniformly through the length f the bolt, and be equal to:

Strain = $E = 0.1"/120" = 8.33 \times 10^{-4}$ "/"

he added stress in the bolt will be:

Stress = E x E, where E = Young's Modulus

Stress = $30 \times 10^6 \times 8.33 \times 10^{-4}$

Stress = 25,000 psi

vhich is approximately equivalent to the initial installa-ion stress in a normally tensioned bolt. Therefore at this oint the bolt would be developing about 50,000 psi r say 40,000 lbs. force in a 1-inch bolt tending to inhibit the rock dilation of 0.1 inch. The longer the bolt, the less force is developed, and therefore the "softer" it acts and the less it inhibits rock dilation.

In contrast, with a fully grouted bolt under the same conditions, the 0.1 inch of dilation strain will be distributed over only that short length of bolt on each side of the joint where the bond between bolt and grout is broken. If this is 5 inches on each side of the joint, then the strain in the steel is: $E = 0.1"/10" = .01$ "/" and Stress = $30 \times 10^6 \times 1 \times 10^{-2} = 300{,}000$ psi, or say 240,000 lbs. force in a 1-inch bolt inhibiting rock dilation, which would be far in excess of the yield and ultimate strength of the normal bolt steel. If the bond were broken 10 inches on each side, this figure would reduce to about 120,000 lbs. In either case, the conclusion to be drawn from these considerations is the same, any finite movement of the rock will cause a very rapid increase in the restraint offered by a grouted bolt.

Conclusion

A fully grouted rock bolt placed and grouted immediately after rock excavation, even though untensioned initially, should be several times more effective than a tensioned but ungrouted bolt in preventing rock dilation.

In making this statement, it should be recognized that fast setting, high early strength, resilient grouts or mortars are indicated. Some minor bond deterioration must be anticipated with subsequent blasting, but this will diminish rapidly as the face moves away, and in any case its effect will be less objectional than the loss of installation tension, which now occurs in ungrouted bolts with adjacent blasting, and permits easier rock dilation.

Ideally, a bolt fully grouted at installation should also be given an initial tension, although this complicates the hardware and installation procedure. Also, to minimize the cost of expendable components, it should not, and need not, be a hollow bolt if improved systems such as pneumatically blown mortar are developed to fill the borehole completely without air pockets. However, even if the unit is a simple untensioned dowel, it should still be more effective than an ungrouted bolt as shown by the analysis given.

*This paper is an extraction from a joint paper presented at the AIME Intermountain Minerals Conference at Vail, Colo., on July 31, 1969 by John J Reed & W D Ortlepp

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or whatever. They just use them and go in and get whatever they're after--coal, lead, or whatever--and then that opening is abandoned. I got much more involved in construction work with bolting that had to be permanent.

Swent: That's the difference.

Reed: Right. However, we found that if you get organized correctly for putting in grouted bar, in some respects they're a lot cheaper. They're just ordinary rebar instead of a fancy bolt with threads and a head and all the rest of it, and they are much more effective than tensioned bolts, and they can never loosen and lose their effectiveness.

Swent: Is that little casing very expensive?

Reed: That little casing is not used any more. That was just an expedient at the time. What I taught them down in Chile when I went down there was to have a pump that would pump a thick consistency of cement paste--no sand in it, just cement and water--a diaphragm pump or some kinds of piston pumps. What you do is pump it through a kind of a stiff hose. You drill a hole, then you run this hose, without any grout coming out of it, clear up to the back of the hole, until you hit the bottom of the hole. Then you turn on the pump, and the grout going up the hose pushes the hose back out of the hole, and there's no air trapped up there. That's the reason you start at the back and come out. When you get through, you've got this hole up in the roof full of grout. If it's a small enough hole, not too much falls out; it's like a pipette, because the air is excluded. This is the messy part; you're liable to get a certain amount on your head. You put the rebar up in there--

Swent: You can still get the rebar to go up in there?

Reed: Yes, because it is a thick liquid or a thin paste. Some of it runs back out, but they learn. Of course, they don't have to fill the hole entirely, either, because you're going to displace quite a bit with the bar. You learn to leave maybe the bottom three feet of hole empty, and that's taken care of by the time you get the bar to the top of the hole. The next thing is what keeps the bar from falling out until it's set? That turns out to be easy. You don't use big, heavy bars; you use at the most a three-quarter-inch bar, more likely five-eighths-inch. In Mexico they even went to half-inch. What they do is stick the bar up there--say it's an eight-foot bar--about four feet, and then you just hang on to this four feet that's hanging out and give it a little bend--a little permanent kink. Then you shove it up, and it's biting on the side

of the hole and you're pushing against that kink, and that takes care of it.

People tell me the Mexicans even reuse the bars. They put the half-inch bars up in the stopes for temporary support, and then they blast down the next layer of rock overhead. Of course, the bolts would come down with the broken ore. They beat the concrete off of them, straighten them out--they'd be bent and twisted--and use them the next shift. Right away you say, "Gee, but they'd be weakened." It turns out they're not weakened; they're actually work-hardened. They're stronger. [laughter]

The grouted rebar has become much more common. In production work, in many places it has--I don't want to use the word "replaced"--

Use of Split Sets in Mining##

Reed: The split set is something that has come along. Jim Scott, who studied rock mechanics and got a doctorate from, I think, the School of Mines in Wisconsin, lives in Rolla, Missouri, and taught at Rolla. He got this idea of a split set, really, perhaps from a little thing called a drift pin in mechanical work, which is a split pin. It's a little tubular pin that's split down one side with a space left open. It's used to retain all kinds of little mechanical things on a shaft, for example. You just tap that into a hole that's a little too small for it, and that makes it squeegee to get into the hole, and then it's hunching itself out against the hole, and it stays there. You can drive it out easily with a pin when necessary.

Perhaps Jim looked at that and said, "Gee, why can't we use that on a bigger scale to hold the rock together?" So that's basically what it is. I think it's 14-gauge rolled steel. I'm sure they make them different sizes for different bore hole sizes--bit sizes. For example, you might have one that was nominally an inch and a half in diameter, with a quarter inch or so gap on one side. It would be, say, six feet long, and one end of it would be swaged down a little bit, sort of conical, so it would go in to get it started in the drill hole. If it's an inch and a half in diameter, you'd drill an inch and three-eighths hole in the rock. Now you've got a hole that's an eighth of an inch undersized as far as this split set is concerned.

On the other end of the split set, the end that's not swaged down, there's a reinforcing ring about a quarter- to three-eighths-

inch round ateel stock, like a big washer. It's welded to the back end of the split set, and that's what's going to hold the plate up against the roof, instead of like a nut or a head on a bolt. To put the thing in place, you drop this, say, six-by-six plate down over the split set until it sits on this ring at the bottom. Then you put the swaged end into the hole, and of course about three or four inches is about as far as it will go, and then it's tight. Then you put a driver on with your air drill and just drive the thing in the hole the whole six feet, until the plate comes right up against the rock.

Again, it's just being held there by the friction on the sides of the hole and this tendency to hunch its shoulders out against the rock. Well, it's awfully quick and easy and cheap; that's the big advantage of it. But, obviously, you drove it in there, and you can pull it out; it'll slide out with sufficient force. If you don't need a whole lot of support--maybe you're just holding up mesh and small pieces of rock--it's good, and millions of them have been made all over the world by Ingersoll-Rand, who took it over. I'm sure they use Jim as a consultant and pay him a royalty on it, because he got a patent, but it's basically Ingersoll-Rand International that makes them now.

They're wonderful for where they'll go. I do have the feeling that sometimes I see them misused on some kind of a permanent job. They may be all right even to hold up temporary support when you're coming along with a concrete lining in the shaft, say, afterward. Okay, fine, but by the same token, they're made of sheet metal and will rust very quickly. Assuming you've always got some water in the ground, you haven't made a permanent reinforcement of the rock when you put in a split set. You've temporarily stabilized it. That's just my analysis. It's been a wonderful thing, but sometimes I think it's overextended in its application. Certainly it was a great contribution.

Swent: Concrete seems to have taken over from timber just about completely.

Reed: Yes, for a variety of reasons. Timber is expensive now to buy, and big timber is scarce. Then there are the people who stand the timber--you don't have any good "Cousin Jack" timbermen any more. Timbering properly is a real art, and you can't find people to do it any more who know how.

Swent: Bolts and grouts and all those things have taken over.

Reed: Yes. They're more permanent, and another big thing is that they're fire-proof. Some of the terrible mine fires have been shafts that were heavily timbered. The Granite Mountain shaft fire in Butte

was one. That's another perfectly good reason for staying away from timber. But it's a variety of reasons; it's a summation of all of them.

Another thing--that's in my little song in that story about my return to Chile--is that timber takes up space and clutters up the space where you're trying to work. So the rock bolts are better, because they leave the space all wide open. They're up in the rock, reinforcing the rock. By the same token, if you're not going to try to put in big, heavy timber sets, you don't have to make the opening so big. You need, say, four feet wide and six feet high for a man to work, but you ended up in the old days putting a set in that was six or seven feet wide and eight feet tall because the set itself took up all the space. Well, when you make an opening bigger, you're making your problem bigger--the support of the ground. In the first place, it costs money to excavate, by the yard; in the second place, the bigger the opening, the weaker it is. So by being able to make the minimum opening that you really need and reinforce it, you've done yourself a double favor.

Also, timber is a passive support. We said, "We support the ground with the timber," or something like that, but really all we were doing was controlling the rate of failure of the ground so that it wouldn't fall on our heads too quickly. The timber didn't take any load until the ground began to fail and moved onto it. Driving a wedge or something--that just takes a little slack out; that has nothing to do, really, with anywhere near the capacity of the timber. It's not pre-loading the timber, in other words.

Swent: What is the next big step going to be? What's going to be the next area for progress in mining?

Reed: Oh, boy.

Swent: Have they gone as far as they can go?

Reed: Problems develop, and somebody solves them, you know. I always have before and I still do look to the South Africans, really, because they're meeting the problems way ahead of the rest of the world--depth, pressure, heat. It's so hot down there, and they've got such a problem of circulating air to cool the people, that if they had a power failure and couldn't keep the fans going, most of the people down there wouldn't last more than twenty minutes or a half an hour. They would die of heat stroke. So they have all kinds of auxiliary power plants to keep the fans going, and they have tremendous refrigeration systems to cool the air at the point of use.

They pump all kinds of cold water around. They took me around and showed me--I've got pictures of a room. I think their basic units were--you know how we have a one-ton air conditioner in a window for a house? They showed me these units that had a rating of five hundred tons each, and there were about five of them in a row. They were cooling ice water on this one deep level and sending it three or four thousand feet deeper, circulating it through heat exchangers and blowing that cold air over the men in the stopes. Then the warm water would come back and run through the machine again; it was just going around and around.

Acclimatization of the men, the black miners--they learned after while that if they just brought a whole bunch of new recruits in out of the bush and sent them down there, some of them were not heat tolerant. In the old days they'd send them all underground, and the ones who suffered heat prostration, if they could get them out before anything happened to them, they'd give them surface work. When I was there in 1967, and I'm sure they're still doing it--they were already highly organized, and they took me to one of these places--they had a big room on surface, kind of like a locker room with benches running in it. It was an acclimation chamber. The atmospheric situation in there--they could control the humidity and the temperature. They'd take these guys in there for an hour a day; they were training them on other things outside, but for an hour a day they went in this chamber. They'd start them with not too hot and not a hundred percent humidity, and gradually build it up.

They had a kind of a metronome, and they all stood there and stepped up on a bench and then down, to the beat of that thing, the whole gang in unison, for about fifteen minutes. Then they'd take their temperature. They'd do it for another fifteen minutes, and they'd take their temperature again. They'd find out if they were tolerant. If their temperature starts going up, they can jerk them out of there right quick, take them outside, and douse them in cold water, and they're not going to lose them. But it's not the same when it happens underground. So they build up their tolerance gradually, and they weed out all the ones who are simply not physically tolerant of heat and assign them to jobs in cool areas.

Then they've got all kinds of things that they've used. They've got plastic vests. You know some of these workers we see around with a down vest on? Well, it looks sort of like that. It's a quilted thing, but it's quilted plastic, and in between is water. They put it in the deep freeze, and they have a whole bunch of these things in a cold box underground. One of these characters that's working hard in the stope puts that on, full of ice, and when he gets it all melted, he gets a new one. So they try things like that, too, to control their body temperatures. I found that

the whites, the bosses, in those mines--and I noticed the same thing in Zaire--felt a great responsibility for the welfare of their black miners.

Swent: They are very valuable.

Reed: Right, but it isn't like you were running around beating them with whips; they're not slaves. The bosses don't feel that they're expendable. Some of them get killed, sure, but some of the white men get killed, too. They feel a great responsibility for the blacks. We have to remember, I think, that those people are really right in out of the bush from a tribal culture. They have to teach them tools and how to wear shoes and a hard hat. Incidentally, along with this acclimation thing they have a model mine right up on the surface. Right there they spend several weeks teaching them how to use the drills, how to set timber packs--how to do all these rudimentary jobs, because they don't know how to use a shovel. If you give them a shovel and tell them to load that car, they're liable to hunker down on their heels with the shovel and load the rocks on the shovel by hand and then carry it over and dump it in the car. I've heard them tell me that. So they need to learn to use tools.

It takes an awful lot of them; there would be thousands of them on a given mine. Once in a while something drastic happens, like a bunch of them stampeded to get from the shaft into the shower room, coming off shift. There was an underground connecting travelway between where they got off the cage at the shaft and the change room, and there was a stairway in it. These guys got to pushing and running--about fifty or a hundred of them--and the first thing you know, somebody tripped on the stairs, and they piled up and some of them smothered and died. It was like a crowd in a theater with a fire or something; they panic. So there are all kinds of ways to have problems, but it doesn't mean that the whites mistreat them.

Swent: Have you been back again?

Reed: Well, I went to Zaire for about a month in 1972, and from there I asked them, and they drove me across into Zambia; it's not very far across the border. One of my ex-students, Chris White, was living there. He had worked a long time as an underground mine manager in Zambia, so I visited him for a few days. Then I flew down through what was then Southern Rhodesia; now it's Zimbabwe. I saw Victoria Falls. That was a great trip. They were in a very tense political situation because Ian Smith was still trying to keep Southern Rhodesia white, you know. They [terrorists] were actually infiltrating the game park in Southern Rhodesia (they just called it Rhodesia then)--the Wanke game preserve. Terrorists were coming

in from Zambia and planting mines in the roads. A couple of tourists were killed by a land mine, driving around looking at the animals in the game park. So things were tense at the border.

I landed on the Zambia side and then rode across the bridge in a bus. A young Rhodesian army fellow was checking the luggage. It was only a busload of us, not very many of us, and he was really going through those suitcases--no x-ray. He was looking for bombs or guns or whatever. One of the lady tourists was quite taken aback by this uncouth treatment of tourists. I really felt sorry for that guy. I wondered what she was thinking about--where was she? They had a tense situation, and she could have been tolerant.

Anyhow, I enjoyed my stay there and went out in the park, and then I flew on to South Africa and spent another few days with Neville and Jennifer [Cook] on that trip. I don't think I went in the mines again.

I saw the same kind of thing up in Zaire. There were Belgian engineers running things. We were doing some research on better drill rounds for the tunnels, Norm Smith (who I told you about earlier) and I. One day we went down with this Belgian fellow, and we get down to the face of the tunnel--and this was all diesel equipment, trucks and so on. To give you an idea--you know, these guys are not real intelligent or educated. There was supposed to be one loader and one truck in the end of that tunnel, and enough ventilation to take care of the diesel smoke. We get down there, and there are about five or six trucks; the electrician's got a truck down there, the plumber's got a truck down there, and the loader and the hauler. They're all down there, and something's holding up the action. All these vehicles and all these people are all down there, with all the engines running. The smoke is so thick you could cut it with a knife, and nobody's got sense enough to get out of there or shut off the engines.

This poor Belgian engineer gets down there--all these guys are blacks--and, man, did he blow up at them and said to just get the heck out of there, and ran them all out of the drift. He was just fit to be tied, because he was afraid the whole crew was going to keel over. That was an example where he was mad just because he was afraid he was going to lose a whole bunch of them, and they didn't realize the danger they were in.

I don't envy them the situation, but then again, from a political point of view I think we're stupid in this country--the do-gooders and all the rest of this disinvestment business. It's counter-productive. We don't understand what the problem's all about, and we want them to solve it our way, easy--one man, one vote. In other words, we want the whites to cut their own throats.

Because all of Africa is an example of what has happened when they've tried to do it one man, one vote. It ends up that they don't even have a vote then; it's a black dictatorship, a tribal dictatorship, and they've got more human rights violations. There's more of that, I think, in those all-black governed countries than there ever was with the whites running it.

You know, half of Africa relies, technically, on South Africa for just about anything you can think of.

Swent: It's the most advanced country.

Reed: Right. All these other countries are calling the South Africans all kinds of names publicly, but at the same time they're using their equipment. In Zaire, everything in the newspaper was about the terrible whites in South Africa. At the same time, there were two big old, beat-up DC-4s that flew in from Southern Rhodesia daily with white crews, clear over Zambia--they didn't have permission to land in Zambia--with nothing but a load of beef. Good Rhodesian beef was flown into Lubumbashi in Zaire <u>every day</u>. They could not land, as I say, on the way in. If they landed with one engine out--they were old, beat-up planes--they had to fly out the same way. They had to take off empty with three engines and fly all the way back across Zambia. They were persona non grata. But, by golly, they were willing to buy their beef. That was an example.

Another thing I remember seeing there was that a lot of explosives in Zaire came from South Africa, and some kind of special resin used for anchoring the bolts in the rock instead of grout. We never mentioned that system, but another way to anchor bolts is with a long plastic sausage which contains resin plus an activator. You shove that up the hole first, and you spin the rebar into it, which tears up the sausage and mixes the catalyst with the resin, and it sets up in just thirty seconds or so. That stuff is very temperature-sensitive for storage. It was made in South Africa, sent in a refrigerated train all the way up to Zaire, and then kept in a refrigerated warehouse until it was used. But again, they were completely dependent on South Africa.

And all the rolling stock on their railroads--they couldn't maintain it themselves; they sent it down to South Africa to be maintained.

Swent: Are you still in touch with the situation down there?

Reed: Oh, not much in South Africa, no. I get some of their publications still.

Professor Neville Cook, University of California at Berkeley

Swent: Were you involved in Neville Cook's coming here to America?

Reed: Yes. Douglas Fuerstenau called me from Hearst Mining Building. He's a metallurgist over here.

Swent: He's the principal investigator of this oral history project.

Reed: I think he was the chairman of the Minerals Science and Technology Department when they decided to reactivate a mining section. He approached me for suggestions, and Neville was my suggestion.

I was very glad to see the department start. I think when he started it was only going to be some graduate students, but very soon they said to go ahead with some undergraduates. He had quite a group of undergraduates at one point.[1] I think all the mining schools have fallen off lately. I don't know what the situation is at Colorado now, except they're way down. We were up well over two hundred in mining, and the total enrollment in the school was on the order of three thousand in the last few years [that I was there]. Now I think it's dropped off a lot from that. I know they have almost more faculty than they have students. I know of two cases: Bill Hustrulid, whom I hired there from Minnesota, is spending a year over at the university mining school in Sweden. John Abel, who was another one of our doctoral candidates at Golden and has gotten up to being a full professor, I think, is down lecturing in Guanajuato, Mexico, this semester.

Swent: I think we've covered all the points I jotted down to ask you. Is there more that you would like to add?

Reed: Let me tell you one story. Neville really got a kick out of it the other day. We were talking languages and accents. There was a fellow named Mike Klugman teaching, basically, mining geology at Colorado. Now, that's a pretty Afrikaaner-sounding name. Actually, he was born and raised in South Africa. It sounds like his father, at least, was Afrikaner background, maybe once removed; that Klugman certainly sounds like it. His mother, I think, was

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[1]For more information on the mining engineering department at Berkeley, see Malcolm McPherson, Brothers in Mining, Pioneering Computer Network Analysis in Ventilation; Teaching at Nottingham and Berkeley; 1965-1991, Regional Oral History Office, University of California, Berkeley, 1992.

Scottish. He got his first degree in geology at the University of Capetown. That means he automatically was bilingual, in Afrikaans and English. When I talked to him, he sounded like he had a broad British accent; that's what we all think when we talk to a South African.

From South Africa he went up to McGill University in Quebec and ended up somewhere along the line with a doctorate. He married a Canadian girl; he was up there several years, obviously. Then he came down and had been several years in Colorado when I knew him. He still sounded like a South African to me, but obviously he had gotten some Canadian accent rubbed off on him, and some American. Finally along comes a situation where some petroleum people down in Texas oil fields wanted to invest in a mine in South Africa. They came to Mike, knowing his background, and they sent him down to Windhoek, which was the capital then of what they called Northwest Africa--you know, they've argued about that place ever since World War I. The South Africans still ran it in the late sixties, when this story took place.

So he goes to Windhoek and examines this property and decides it's a good bet. He contacts his principal back here, and they say, "Go ahead and negotiate a lease or a buy-out, some kind of a deal, so we can get control of it."

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Reed: So they told him to go ahead and negotiate this thing. It turns out that all the principals who owned it were Afrikaaners. Here they gathered around this big table and started negotiating all the fine points of this deal, of course in English, mind you. Apparently the Afrikaaners don't recognize that this is a South African they're talking to and dealing with; they had no clue. As they go along in the negotiations, if they get to a kind of a sticky point where they want a little bit of consultation between themselves as to how they're going to arrange their tactics or whatever, they relapse into Afrikaans language and carry on this discussion with all their tactics and how they're going to negotiate this thing. Klugman just kind of looks at the ceiling and pretends that he doesn't understand a word they're saying--pretends not to be offended or anything like that.

Finally, after two or three days of this they get it all worked out and the papers signed. He stands up and goes to the door to leave, and he turns around and bids them goodbye in Afrikaans. [laughter] That's one of my favorite stories, and for anyone who's been to South Africa it's especially humorous. It does show how manner of speech can get changed and be non-

identifiable. It's like my not knowing I had a Chilean accent for a long time.

When we went to Russia, I had this interpreter assigned to me, but I lived in this hotel with no people in there speaking English. I'd come out in the morning with several words I wished I'd known--simple words like butter, bread, thank you, please, where to. My interpreter would tell me, so I started developing this real simple little vocabulary. After while I really flabbergasted some of my other friends who were in other hotels. I could ask for a glass of milk or something else. But they all laughed at me, because they said I was the only person they ever heard speak Russian with a Spanish accent. [laughter]

Further Recollections of Chile

Reed: The Cooks have a nice aquarium in their sun porch, and they were giving it its weekly vacuum cleaning the other day. It reminded me--I think I told you that I bought a whole houseful of furniture six months before I was married. There was a master mechanic for the mine there, named McLean, who had worked over in Uruguay or somewhere on the other side and knew Buenos Aires was a wonderful city to visit and shop in. In Chile at that time--this was during the war [World War II] and the end of the war--boy, the stores were just about down to absolute basics. You couldn't buy Mason jar lids for canning--you know, what we would consider really basic things. A lot of stuff was rationed; tea was rationed, and so forth.

When I started thinking with my fiance about setting up housekeeping, I had some basic furniture, but we needed all kinds of other things that you just couldn't get there. Furthermore, we were talking about going on our honeymoon someplace we'd enjoy.

Swent: Where were you married? Up here?

Reed: No, we were married down there. I'd been talking a lot with this McLean, and he was telling me what a wonderful place B.A. was, and I ought to go there for my honeymoon, to start with. I had had an aquarium as a boy in Los Angeles, a fifteen-gallon aquarium, and I enjoyed sitting and watching the fish. I was thinking to myself, in this stark area where Sewell was--there was nothing green outside, as I told you, and you couldn't have a garden or anything like that. I thought, "Boy, an aquarium with tropical fish in the living room would be a little bit of green life right in there all the time, and that would be a big deal."

But they didn't know what tropical fish were in Chile; they didn't know what an aquarium was. I mean, I couldn't buy one, and I don't think you could even buy goldfish. I started talking again with McLean, and he says, "Oh, they've got pet stores in Buenos Aires with all the fancy tropical fish." So I got busy and sketched out an aquarium, and somebody down in the mine shops made me the framework and cut me the glass. I had an awful mess, which I won't go into, cementing the glass in with a kind of a tar stuff. They didn't have the right thing, so I made do.

Anyhow, I got the aquarium built. When we went over on our honeymoon, then, indeed our eyes bugged out at all the shopping. We spent most of our honeymoon shopping and buying drape material--all kinds of stuff. Amongst other things, we found a pet store. We knew what we wanted, and we got a big liter preserving jar, which was about a foot tall, pretty big, and had a big glass cap with a gasket that fit on it, and a metal clip over the top; it wasn't a metal screw-on lid. We figured that would do for the trip home.

But then we got the idea that we ought to check with export-import--the politics of carrying live fish to Chile. That was a mistake, because we spent I don't know how many days going around from one damned bureaucratic office to another--probably because we weren't offering them any bribes. They'd send us from hither to yon, and after a couple of days of that we weren't getting anywhere. We decided we might as well just play it by ear.

The night before we were to leave, we had our jar, and we went to the pet store and got about two dozen little fish, a few of each variety. We took them back to the hotel. In the first place, it's in the middle of winter; it was July. It was cold, and they've got to be warm, so I rigged up a makeshift heater with a table lamp and a towel until morning. Now, this was during Peron's time, and everything was pretty tight politically and immigrationwise. Also, you may know that in those days--before jets--you always left at daylight, it seemed. So we had to be at the airport at five in the morning in the dark.

We get there with all our bundles, a lot of them to be hand carried on the plane, including this jug in a paper bag under my coat, trying to keep it not only warm but out of sight. The first thing you did was go through immigration, into a big room that was like a big wire cage. Everybody on that plane was in that cage for an hour or so. It was cold and dreary, and there were some electric space heaters scattered around the sides. One of us would stand over by a heater with the fish under our coat and open the coat at the bottom so the heat would go in and come up and keep the fish out of sight and warm.

Then they were inspecting the luggage at this point. So you took your suitcases and everything over to a bench, and they checked that all over and made sure of it. Then they had their *timbre*--you know how they use the *timbre*, the rubber stamp--and they put their customs *timbre* on the outside of every package. Well, of course I didn't have the fish over there, but I had all these other packages stamped. I carried them all back over to the corner where my wife was, and then we carefully switched the wrappings from the fish to the curtains and the curtains to the fish. So now the fish had a *timbre* stamp on it; it was all wrapped up in paper, but it had a stamp on it.

Then I went back to the inspector, and I said, "Gee, here's a package that I forgot to get over here," so he put his *timbre* on that. Finally we were ready to get on the plane. Meantime, after all this nightlife and so forth, I guess I had gotten something that didn't set well with me the night before, and I was beginning to get nauseated. I didn't know whether I was going to make it to the plane before I had to find a place to relieve my stomach. And all this nervousness wasn't helping anything. I guess we got up near the head of the line, because we were about the first ones to climb on. If you remember a DC-3, it's an old tail-dragger and narrow, and we climbed in at the stern. We grabbed the first two seats, just ahead of the door, and all the rest of the people were traipsing in behind us.

Well, I just barely made it to the seat and got the barf bag out and proceeded to half fill it. We hadn't even started the engines yet [laughs]. That always struck me as comical as the dickens, because here I was airsick before we even started the engines. I wondered what all these other people thought as they were getting on. Well, that was just a sidelight.

We finally took off. Argentina is a big, long, flat pampa, and then finally a big hump to go over the Andes. We're droning across this long pampa, we're finally getting relaxed, and the sun has come out. Of course, I'm worrying about the fish all the time, so as soon as I could I got the lid off the top and got them some air. We're cruising along and everything is kind of quiet, and I notice that next to me, out in the aisle, the sun is coming in the other side and shining nice sunny patches along the aisle. So I set the jar of fish down there by the side of my seat so the fish got some fresh air and a little bit of radiant heat from the sun. They were looking happy.

About this time the steward comes along with a tray of coffee or something, and damn if he didn't kick over the jar. Here's these two dozen little fish flipping all around all over the

place--in the aisle, under the seats, across the aisle. All the passengers, very solicitous, were down on their hands and knees apologizing and catching fish and trying not to pinch them or hurt them. Somebody throws a little water in the jug. You know, I think we got them all back in the jug, and the steward got some warm water in there. He was very apologetic, of course. He rushed the jar up to the cockpit and bubbled oxygen into them. And we saved those fish. I think we must have lost two or three of the two dozen fish, but we got them home eventually. That was the damnedest experience. We had them for a long time in our aquarium. So any time I see tropical fish, that crazy story comes to mind.

It is also a comment on what was available down there in stores generally. Chile had tremendous import control, and they just wouldn't let anything in. They thought they were protecting home industry.

Swent: It is also very, very far away from any source of things, isn't it?

Reed: This is true, but so is B.A. But they had a Harrod's store.

Swent: It's easier, though, to go across the Atlantic to Argentina than it is to get over to Chile, isn't it?

Reed: Well, I suppose, but you could have sent it across on a train or gone around to Valparaiso.

Swent: Yes, through the canal.

Reed: Right, and the Grace Line boats ran up and down the West Coast and through the canal to New York--and to the West Coast, as a matter of fact.

Swent: That's true. It was political rather than geographical.

Reed: Yes, it was really political. You just couldn't import anything down there. Of course, it was hard on the company from a technical point of view. They had an awful time. The Chileans really milked the company in the way of taxes. They got about 80 percent of the benefit of the mining in taxes and so forth. In fact, it got to be such a stand-off, and the unions were so Communist and so down on American exploiting--the private company--that the company actually gave them 51 percent, and it all became a partnership on a voluntary basis. But that made the country the grand *patron* of the enterprise, so then when the workers wanted to strike they were striking against their own country, their own government, not against those filthy Americans. So that changed things around, and in spite of the fact that from that point on technically Kennecott

only owned half the operation, I think they actually ended up netting more income from that half.

Swent: It was a good move, then.

Reed: Yes. Eventually, when Allende took over, he took it over entirely.

Swent: Did you see this coming in Chile?

Reed: We could certainly see that Communist business. Chile was ridiculous, politically. They had about sixteen or eighteen different political parties, and they were all splintered and wouldn't work together, except the Communists. The Communists held together in a block of about 30 or 35 percent of the total vote. By virtue of that, ultimately that's how Allende got in. It wasn't because he won the popular vote; he was a minority, but the others wouldn't stick together and keep him out. That's why he got in, in a so-called democratic election, and all the liberals and the do-gooders made such hay out of that.

Something interesting along that line--we knew how Communist the workers were. Indeed, there was a rumor that the mine fire was really started as an act of sabotage that got out of hand. I mean, I'm sure nobody wanted to kill all those people.

Swent: Had there been other similar acts?

Reed: Not that so much, although we gringos knew amongst ourselves that there were one or two young Americans down there during the war who were supposed to be engineers in the organization and who we all kind of figured were U.S. agents to keep an eye on things and worry about sabotage, because that copper was important. The fire started between seven and eight o'clock in the morning, at the very beginning of the day shift, and the train, the *autocarril*, took several hours to get up from Rancagua. A Communist *diputado*--somebody from the national congress in Santiago and big with the Communist labor unions--showed up at the mine very soon after the fire started.

Remember I told you that the three top men all arrived on Teniente 5 level just before the explosion and were fighting to shut off the smoke and start the rescue operations? This *diputado* showed up there, underground in the mine, raising all kinds of hell about how this was all a gringo plot. It was very suspicious that he showed up there, almost as if--it made it look like he must have known it was coming; he got himself ready. How did he get all the way from Santiago to Rancagua, up the hill, and into the mine, all within a few hours?

Swent: And knew there was a fire.

Reed: Yes. He was shouting and ranting and waving his arms at these superintendents down there when they were still trying to find out how to save what was left. One of the survivors whom I've talked to told me that somebody was sent down from New York afterward to investigate. I think it might have been Parker; that's the name that pops into my mind, and I think Parker was one of those fellows who was killed in the later plane crash. Anyhow, somebody from the Kennecott head office in New York was sent down there to make a real in-depth study of what really happened, and they assigned my friend Russell Fitch to him. Fitch worked with him for several weeks, and they went over everything with a fine-tooth comb, visiting the site of the fire and everything.

Later some of that material was written up in a confidential report to the U.S. Bureau of Mines and never made public. When I came here and gave my paper in 1989, there was a Bureau of Mines fellow who came to me afterwards and said, "I've read an article about this fire. I don't have it with me, but you might be interested." And, by golly, he sent me a copy of it. It goes into several theories, but some things about it we were pretty sure were wrong. I sent it to Fitch, and he read it, too. He's pretty sure that they were wrong conclusions, because he was there, after all. There was obviously a lot of suspicion that this might have been started as a set fire, with no idea, of course, that it would become such a disaster.

We were very much aware that some of the people in our work crews were really just there as rabble-rousers. They might say they were miners, and they might be pretty good miners, but their main concern was to foul things up, one way or the other. We knew a lot of them were basically Communists, but we didn't have any lists or anything.

There was a presidential election in 1946 between Gonzalez Videla and a Communist candidate. Gonzalez Videla really campaigned and talked as if he was going to be sympathetic to the Communist cause, so he got the Communist vote. It was kind of comical. He catered to them, so he got in, really, due to the Communist vote. He had no more got in, than he placed our whole area under martial law. He handed the company big long lists of names, and they were anywhere from out in the offices to underground workers, you name it--a couple hundred men. They were all Communist Party members. I don't know where he got the information, but they had them all pegged. Our company was not given any choice in the matter. Some on the lists were bosses. He rounded up all the card-carrying Communists that he could get with the military, and he shipped them all off to concentration camps up

in the desert in the north of Chile. He just put the kibosh on the Communist thing. That was a very interesting episode. Like I say, we lost some of our bosses, some of our best miners. It was a real peculiar situation. I remember that very well.

For his inauguration ceremony--different countries send representatives, so our government sent down the battleship Wisconsin--it was brand-new then; I don't think it had even got into the war--and an aircraft carrier and a couple of destroyers or something.

Swent: This must have been after the war had ended.

Reed: Yes, in 1946. I remember we went to Viña del Mar, which is down near Valparaiso, and we went aboard. That was quite a thrill, to get hoisted aboard the aircraft carrier and the Wisconsin. We've got pictures taken on those boats.

Politics in Chile has always been very mixed up and unpredictable, and I think it's that way right now. I'm sure that's why Pinochet held on to things so tight, hopefully long enough for the populace to get it through their heads that they had to work together. Now it's a question in my mind whether they're going to remember that lesson. The trouble is that a lot of the young people don't remember what it was like under Allende, and it was really bad.

Swent: Well, Bolivar said it was like plowing the sea. It hasn't changed much in a long time, has it?

One question I wanted to ask you, and I don't think I have yet, was about mining equipment that you used in Chile. You imported most of your equipment, did you?

Reed: Oh, yes, mechanical equipment. I think everything down there was pretty old and rudimentary. I can't even tell you for sure what make of drills, but I think they were Ingersoll or Gardner-Denver or something like that from the States. There wasn't anything very fancy, you know. In the beginning we didn't have mucking machines or loaders; it was all hand loading.

Swent: Where did you first meet EIMCO mucking machines?[1]

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[1]Joseph Rosenblatt, EIMCO: Pioneer in Underground Mining Machinery and Process Equipment, 1926-1963, Regional Oral History Office, University of California at Berkeley, 1992.

Reed: Down there. They brought in two old used ones from somewhere; I don't know where the heck they got them. Nobody knew how to use them. I knew how they ought to work, but I don't think I'd ever used one myself. But I went out in a drift in a muck pile, hooked a car on the back, and learned to use it, and then stood there while a Chilean learned to use it, and it became his machine.

I think I was out of the mine before the mine started using any better rock drills.

Swent: You mentioned that you wished they had had things like slushers.

Reed: Yes, and electric blasting. I think they were finally using electric blasting just in the chute blasting, but they hadn't taken to using it up in the--well, in the undercut we might have used Primacord or something like that. Remember, I told you what a headache that was, trying to light all those fuses.

Swent: This wasn't entirely because they were so backward; it was partly because they just couldn't get it?

Reed: Oh, no, they could have ordered it.

Swent: Were they allowed to import it?

Reed: Oh, I think so. Ultimately they did. It was just, "If it was good enough for us, it's good enough for you" type of thing. And make it simple. There's nothing simpler than a fuse, even when you've got 150 of them to light.

When I got out of the mine and down in Coya in the hydroelectric job--for example, we had one gravel road that went up to the upper intake of the Pangal power plant. It must have been ten or twelve miles of gravel road up there, and it had to be maintained. My road crew was an old beat-up Ford dump truck and a driver, and supposedly a foreman--he was just like a *capataz*--and about eight guys with picks and shovels and rakes and wheelbarrows. That's what maintained the road. Most of them lived along that ten miles of road, and each one kind of took it upon himself to fill the chuck-holes for one mile opposite where he lived.

I don't know who it was who finally convinced somebody to finally get a road grader; the obvious thing we needed was a road grader, not that I'd ever had one or used one. The cheapest road grader they could get was nothing but an Allis Chalmers farm tractor that they had stretched the frame on a little bit and hung a blade underneath it, and all hand controls--no hydraulics; really rudimentary. They didn't even call it a road grader; they called it a road patrol.

So that arrived in the dead middle of summer. I can remember that nobody knew how to run it, so I had to find out what to do with it. I went out on the gravel road, baked hard as concrete, and I started trying to run along with that thing and let that blade down. It just jumped all over the road, and sparks were flying. So one of the first lessons we learned was that you only use the grader after a good rain.

##

Reed: After that, the entire road was always in far better condition than this whole crew could have ever done it. One of the chauffeurs from the garage did the road grading, I think, four or five times a year, that was all. Of course, we found other work for the crew; we didn't put them out of work. But we had a whole lot better road with a lot less trouble.

Then we finally got two D-7 Caterpillar bulldozers (actually, angledozers) to make the bench for this new pipeline that I told you about. Again, nobody there had ever run a bulldozer, and neither had I. First we had to learn to start it. It had an electric starter for a little gasoline engine, which had the power to turn and start the big diesel. We did a little gentle pushing around, and finally somebody decided they could learn to run it. Ultimately we had some pretty good bulldozer operators.

Another comical thing--when I was doing that concrete work in the power house, we had a half-yard concrete mixer outside. There was no such thing as a ready-mix plant. You didn't order your concrete; you made it. I think I had two half-yard mixers mounted outside the power house, so while one was mixing you were emptying the other. We had a thousand cubic yards of concrete to place, so it was a lot of concrete I was talking about.

The only way I could get it into the powerhouse from outside was with wheelbarrows. I didn't even have deep construction type wheelbarrows; I had the garden variety, these real flat ones. Well, you can imagine trying to carry soupy concrete--of course we tried not to get it too soupy, but you can't put very much in that kind of wheelbarrows without spilling it, so that meant a lot of people. I had to have eight men with wheelbarrows to empty one batch. It was an awful gang of people going back and forth with wheelbarrows, and there was continuous spillage along the way.

So I really was looking for a better way to transport concrete. I think I instigated this, long after the war. I began to read civil engineering catalogues, and they'd come up with these little gasoline motorized buggies for concrete--a little tricycle

sort of a cart with a gasoline engine under it and a big, deep bucket. It would go through a three-foot doorway and carry a quarter of a yard, so two trips with this thing--bing, bing--and I'd empty the batch in the mixer. And I could go a quarter of a mile if I wanted to, because it would go twenty miles an hour.

The funny part about it was that it was like a tricycle and had little mini-dual wheels up front underneath the big, heavy load. At the back it had two wheels right together which were driving and steering wheels, and they were under a great big horizontal bull gear about two feet in diameter. On top of that gear was a little Briggs & Stratton gasoline engine. Sitting up over that whole thing on the seat was the driver, with the engine right under him on that bull gear. The way you steered was that the steering wheel had a little pinion gear that worked on the big bull gear. It made it tremendously maneuverable, because you could turn the drive wheels, right underneath your seat, 360 degrees. You could come up and make a right angle turn, or you could turn it clear around and back out. It was absolutely marvelous for maneuverability.

However, there was something else. [laughs] When it was loaded and that quarter yard of concrete was up front, right down on the axle with those front dual wheels, it was very stable. But when you unloaded it, after you'd dumped the load, or if you were running around empty, then if you went down fifteen miles an hour and suddenly turned the steering wheel, it tried to go sideways and would flip and throw the driver like a horse; it would throw him clean off, and the rig would tumble.

I had about eight men in my crew, and I put them one at a time on this thing. [laughs] The first seven of them, I guess within five minutes it would throw one of them, and he'd never go near it again. He just couldn't get the hang of slowing down before he turned. It had other little related idiosyncrasies. If you started up a side hill and it stalled out, there was no way you could turn it around on a hill; it would flop over. You had to back down. Going up and down hill, you had to point it straight up and down the slope.

I finally found one young fellow who was kind of cautious, and he learned to run it and appreciate it. Boy, it was great. I laid back porch slabs all over camp without moving the concrete mixer. It was great. Then I got sick. While I was sick, they started doing the work up at Pangal power plant, with a lot of concrete to pour. In fact, I think that's what they really bought this thing for, primarily. By this time we'd learned how to use it to great advantage. I was sick and away in the states.

Well, they got that thing up there, and they had to tram out on a trestle to where they needed the concrete. It was perfectly okay, if they'd have kept the guy on it who knew what he was doing, but I guess they didn't take this young fellow with them. In the end, they were using that darned thing up there for a big job--they took the engine off of it and trammed it by hand; pushed it by hand, because they were afraid of it. They were afraid to get out on that trestle with it, and they started pushing it by hand. Then they said, "We might as well not have the engine on it; that just makes it heavier." That's an example of trying to get modern equipment. First it's getting it in, and then it's learning how to use it and getting the workers to accept and appreciate it.

Swent: Do you see any big breakthroughs in mining equipment, or have they gone as far as they can go?

Reed: I'm sure there'll always be new improvements. Somebody always thinks of something else. I've always been a big believer in looking around and seeing what other people are doing and not reinventing the wheel. Not being invented here is no reason for not using something, and I've run across that a lot. Even now I'm working with Bob Loofbourow from Minnesota. Bob used to be with E. J. Longyear out of Minneapolis, and he has gotten involved--and I have, too--with underground storage chambers for liquid petroleum products like propane and butane and that sort of thing. They mine out a kind of small room-and-pillar mine about 400 or 450 feet below surface, and they use it to store LPG, and it's available when you need more, as surge capacity, near the point of use.

Now he's gotten interested in the possibility of storing up surge capacity of natural gas around big cities. For example, the pipeline that brings the natural gas here to California from Canada comes right past Vancouver, Seattle, and Portland. Although it may be three feet in diameter, such a pipeline can only carry so much gas. In cold winter weather when everybody starts using a whole lot more than usual, the pipeline can't carry enough and so somebody runs short. Around a big city, if you had a reservoir, you'd fill it in the warm weather and use it in the cold weather. They used an old coal mine north of Denver as a storage, and at other places they've used aquifers--gas fields that have a tight bed of rock over them. They've actually pumped the gas in under pressure into the pores of the rock, and then when they need it they bring it out. One disadvantage of those is that the rate at which the gas will come out through the rock pores is limited. It's not like having a tankful, with freeflow out. That's the reason for the underground openings; that's one advantage. They cost more to make, but they give full flow easily.

Mr. Loofbourow approached me, and I've been looking into it with him. This discussion I had with Tor Brekke yesterday is an example. Tor is very familiar with what's going on in Scandanavia. He's Norwegian and visits there regularly. He told me some very interesting things. Apparently, from what he said, they're way ahead of us on conserving energy and storing gas like this in big chambers and so on. So I think we have a lot to learn, and we don't have to experiment and learn it all from scratch here. If we contact the right people and get the right publications we can learn from there. That's what I was doing with the rock drills in Missouri. I got the idea from Germany.

Underground Storage of Nuclear Waste

Swent: Have you gotten into underground storage of nuclear waste?

Reed: A little bit, on a consulting basis. That, to me, is a frustrating business. I know a man named Bill McClain, who got his doctorate in about 1955. I met him first at a rock mechanics symposium in 1956 in Colorado, and he was working on underground storage of nuclear waste. He was working then for the government out of Oak Ridge, Tennessee. He had just gone to work for them in 1956. He's still there, and he's still working on the same thing. After thirty-five years, our government is still investigating how and where to store spent nuclear fuel undergound. None has been so stored yet!

When Bill started, he was talking about burying it in the salt beds in Salina, Kansas. They've moved all over the country since: "Not in my backyard," everyone says. They're worrying about it in Carlsbad, New Mexico, in salt. They're finally testing it in what seems like the logical place, Las Vegas in the tuff. At one point they were also looking at jointed basalt, three thousand feet deep, under Hanford, Washington. Now, that was the most ridiculous environment to think about, but that's a bunch of bureaucrats for you. They want to keep their jobs, and Hanford is a big research center.

There's nothing but great big basalt floes in eastern Washington, and basalt is notoriously full of cracks and fractures--you know, columnar basalt and all that sort of thing. But at Hanford they claim--God knows how much they spent drilling holes--that somewhere down near three thousand feet there was a two- or three-hundred-foot thick bed of basalt that was perfect. They wanted to go down there and mine out an expanding and ongoing array of large chambers where everything would be safe in

perpetuity. I don't know if you've heard much about storing this nuclear waste, but they've got all kinds of qualifications on it.

I got a call from an outfit called CERT, the Council of Energy Resource Tribes, or the energy-owning Indian tribes. It's a sort of cooperative legal entity to protect Indians' rights, especially for the Indian tribes that have some coal, oil, or gas on their reservation. The big thing here was that the Indians that had their fishing rights on the Columbia River didn't want radioactive salmon, so they were bucking the idea of making this experimental storage facility for nuclear waste under Hanford, which is right on the bank of the river.

They sent me a whole bunch of stuff to read, and then I went up to a seminar at Hanford. Different people told why they thought it was good there and why it was bad there. I came down very hard on why it was bad there, because, you know, such storage has got to be absolutely watertight forever; it can't migrate into the ground water or anything. Well, yumpin' yiminy, I know what it's like to try to seal a bunch of rock like that, and they're talking about a big area and absolutely sealing it. I mean, it might be possible to cut the flow a half or three quarters, but that isn't sealed, and not forever. And what are they going to do with all this water they're pumping out? It's going to end up in the river eventually; they've got to get rid of it.

It just all seemed to me ridiculous. The water table, incidentally, was only a few hundred feet below surface, so the pressure would be way over a thousand psi on the ground water down there where they would be trying to work. I already know that we almost had a disaster at 350 psi in Missouri. You'd better get in a bunch of South Africans if you're going to do it there at Hanford.

At the same time the government had narrowed it down to where they were considering three sites. Hanford was one, the Nevada Test Site was one, and Carlsbad I think was the third one. Finally we got them to throw out Hanford, and they're working in Nevada. Over there the government already owns the land, so they don't have to fight with any environmentalists. They've already got it halfway contaminated anyhow, with all the nuclear shots and the testing that's gone on there. The most important thing, where they want to put it is a hundred feet or more above the water table in a desert region. It's just so much more attractive a situation that I don't understand--well, like I say, I do understand, just somebody trying to maintain their bureaucracy and their jobs. But I sure don't blame the Indians. [laughs]

Swent: Do you want to say anything about the national and international organizations--AIME, CIMM, International Society for Rock Mechanics? Do you want to mention the place these professional societies have played in your life?

Reed: One thing I've always thought--mostly after I went to South Africa, I guess, or at least when I became aware that the South African Chamber of Mines is not a government entity.

Swent: No, it's not like our Bureau of Mines.

Reed: Right, it's an industry-supported cooperative. It started off with its only function to recruit the native labor out in the bush for all the mines, and then they were distributed as the mines needed them. One central agency did it all--they ran their own airline and busline and everything else, all over the southern half of Africa, recruiting those guys. That's what the Chamber of Mines was originally set up for.

It may have been that a lot of this actual technical cooperative mining research was coming alive about the time Neville called me. I don't know how long that had been going on. But anyhow, I became very impressed that they were doing very high level technical research, with the emphasis on applied research, even though some of it was pretty fundamental. But it was totally supported and encouraged by the mining companies themselves, without any government involvement. The mining people would come in on a regular basis and sit in committee and discuss what was going on, the progress, which way they ought to go. As soon as anything got ready to be tested, they were right there, Johnny-on-the-spot, "Bring it over; try it on my mine."

There is no such organization in this country. It was suggested in a paper to AIME in February 1961 and to the American Mining Congress in January 1968. The American Mining Congress is industry-supported, but their only real purpose in life is lobbying, isn't it? It's to deal with the government on a cooperative basis. It's lobbying, is what you'd call it, and trying to promote the general interests of the mining industry. I thought they are the logical ones to sponsor their own research at schools, if they don't want to have their own labs, or put up a lab. It was suggested in those papers that they pick out a few schools as mining research centers and have them spotted around the country in different mining regions. Each one might concentrate its research efforts on an appropriate aspect of mining.

That has never come to pass.

Swent: Is the Bureau of Mines research limited?

Reed: Well, I feel that is is often too theoretical. It's too disconnected from reality. It doesn't have a very good rapport with the industry, and a lot of the people working in the Bureau of Mines have never worked in industry. They maybe technical marvels, but if they don't really underatand practical situations or have any experience--. This isn't always the case, but it's become more so in recent years. In fact, I used to try to encourage my students. A lot of them had jobs offered from the Bureau of Mines. My advice was, "Don't do it to start with. Go into industry and work a few years, and then if you want to go to the Bureau of Mines, fine. Then you'll do something worthwhile in the Bureau of Mines." But if you go in the Bureau of Mines in the first place, you'll get all wrapped up in the research and won't know the difference between something that's practical and something that's theoretical.

It isn't that they haven't come up with something useful; they have. And in the old days, I think more of the people that worked for the Bureau of Mines were practical people, especially in safety and that aspect. But it's gotten away from that more and more. I still think there ought to be more not only industry-supported but industry-directed research, whether it be, like I say, in schools or start their own laboratory. Like South Africa. I think there's a reason South Africa is so far ahead of everybody else, because they are doing that and have been doing so for a long time.

Our industry people, to my feeling, don't cooperate that much. Sure, you can visit another guy's mine, and he'll give you an idea of how he does this or that. That's great, and you learn a lot that way. But it isn't the same as having an organized program.

Swent: Some of the companies have their own metallurgical laboratories.

Reed: Yes, they have for a long time.

Swent: But not mining.

Reed: A few more did after St. Joe got going with me. Kennecott, I think, came up with one, and some of the others for a while. I don't know how much they stuck with it. One of the things that got me a little bit, even at St. Joe--I mean, I was happy to go there, but you got the feeling pretty soon that whereas they might be real sympathetic to your work, there was no way that your job, your salary, your prestige, or whatever, was ever going to get up on a par with the operations people. You know, the guy who put the rock in the box and rang the cash register was first in priority of everything--in appreciation and so forth.

The young fellows who were working for me got a raise every six months or a year, but if they really wanted to make money they had to leave the research department and go start in the production department--become a shift boss or something like that. And that's exactly what Dick Bullock did, as far as that goes. He went out of research and into the production area, and he became a mine manager after several years and was making probably twice what he'd been making working in research. He was moved back in to replace me later, and I don't know how the salary worked out then.

It seems to me it was a question sometimes of what was the real significance to the company. Economically there was a heck of a significance to what we came up with. It saved the company lots and lots of money in those new mines, it made them so efficient. Well, shouldn't that be reflected back somehow? Either make the department bigger or something. You'd think they'd see that it was money well spent. When I went there, the budget for my whole little department hierarchy, which was three of us and a secretary, and a little bit of material we bought to use, was something like $50,000 a year--all our salaries and everything. Well, that was a drop in the bucket, you know. I thought to myself, after two or three years, if we came up with some good ideas, "If that $50,000 got this much benefit, what would $100,000 do?" Actually, I was reacting to Parkinson's Law, too; I wanted to build my department. I don't know what kind of answer you'd get on this out of somebody like Jim Boyd.[1]

Swent: Apparently it's a dilemma in every industry, isn't it? Deciding how much to put into research and development.

Reed: Sure, I'm not the first one. But the mining industry certainly is way behind all the rest of the industry in spending money on the general idea of R and D. You're right that a lot more has been spent in the extractive end--the metallurgical end--because they've already spent the money to get the rock out of the ground, and any small improvement in recovery is direct gain or bonus.

Swent: They have to do something with it.

Reed: Yes, and the tailings are what you are throwing away. So, boy, anything they can figure out to get a little bit more out--one percent more--it'll pay for itself, so they're willing to have somebody really fuss around with the test tubes and all the rest of it. They see an immediate benefit, a bottom line.

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[1]James Boyd, Minerals and Critical Materials Management: Military and Government Administrator and Mining Executive, 1941-1987, Regional Oral History Office, University of California at Berkeley, 1988.

I've enjoyed what I've done, and I think it was significant. As far as the industry is concerned, I think they could do more of it with good benefit.

Swent: It's a much maligned industry.

Reed: They need to do a lot of PR with the public, that'a for aure, to get their image better. They're working on that, I guess, too, but I swear that some of the environmental things are pretty outlandish to me. They've driven practically all the smelters--lead, zinc, and copper--out of the country. Maybe we'll never have another world war that will last two or three years, but I hate to think what will happen if we do. We didn't have any shipping at all there for a while in the beginning of the war. What would have happened if we didn't have any production inside the country? What if everything we needed was coming across the sea? Talk about economic sanctions--we'd have been sealed off, that's all. Yet we've put ourselves in that position now--we couldn't go back to producing the minerals we need in-house now if we wanted to. It would take a long time. This isn't something that you can just turn on, like a water tap.

Swent: This has been a wonderful interview.

Reed: I have a feeling sometimes that I wander too much, but I've enjoyed it and want to thank you for your help and interest.

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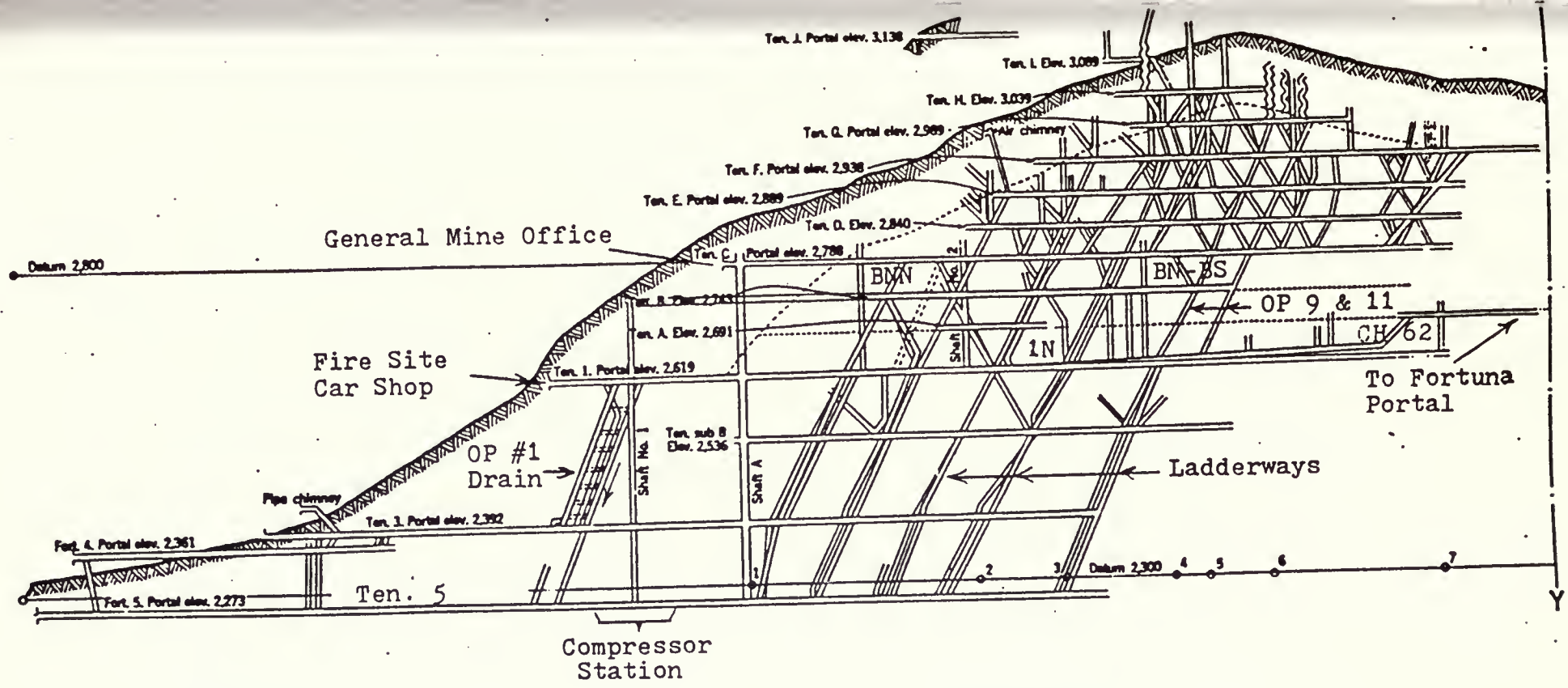

Figure 1 VERTICAL SECTION OF BRADEN MINE
APPROXIMATELY ALONG HANGING WALL

From USBM IC 6565, 1932

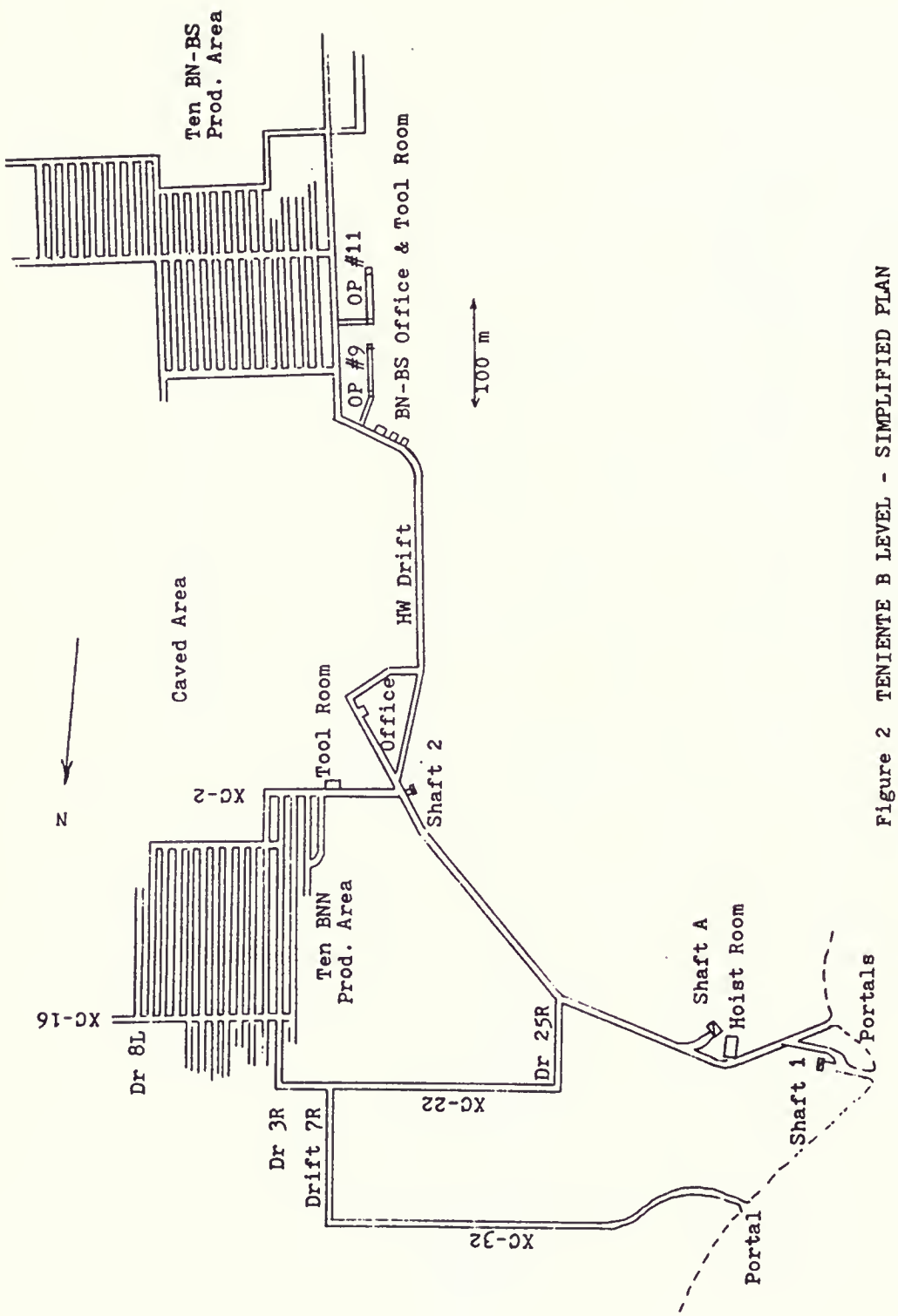

Figure 2 TENIENTE B LEVEL - SIMPLIFIED PLAN

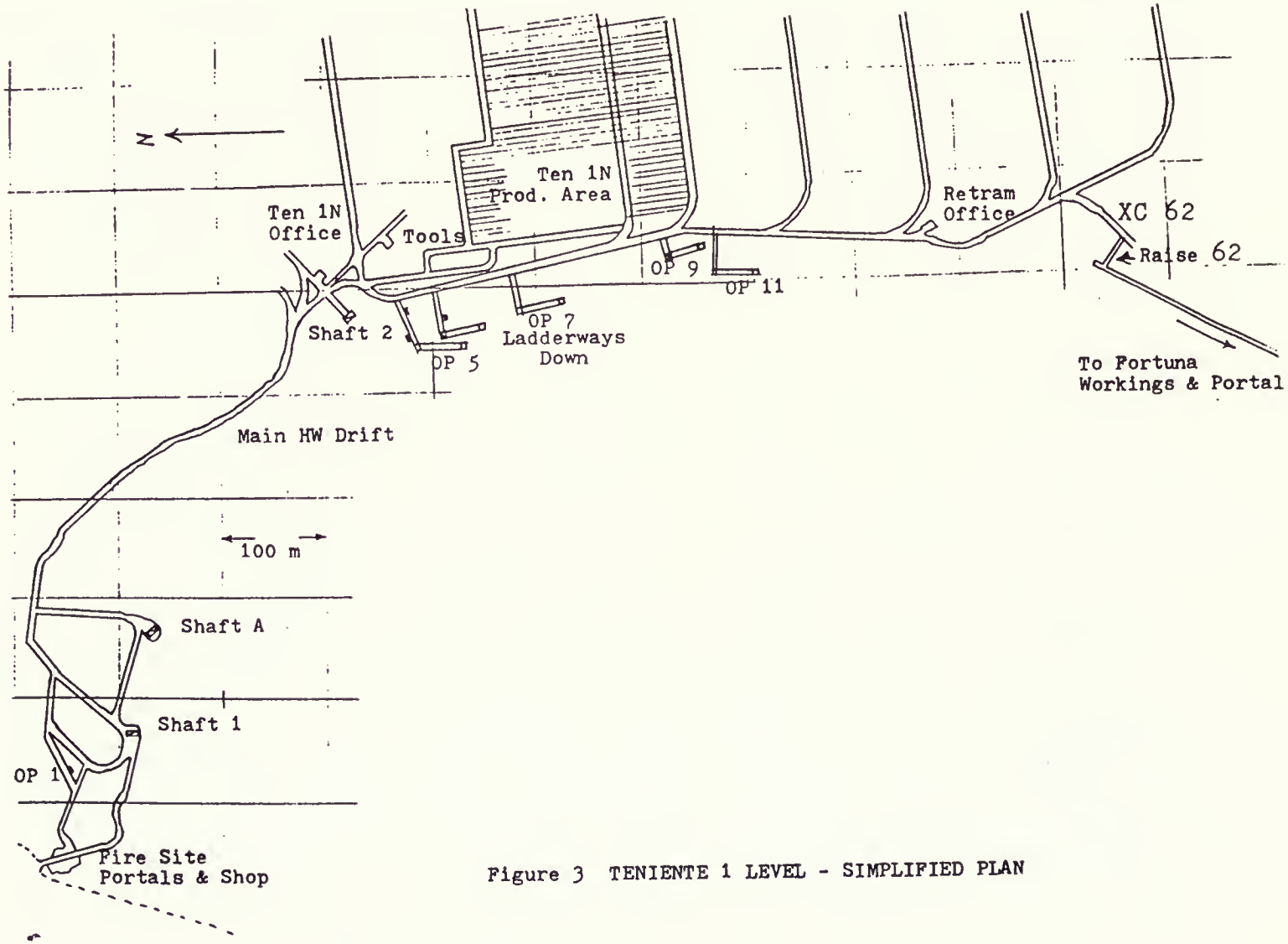

Figure 3 TENIENTE 1 LEVEL - SIMPLIFIED PLAN

To Prof. Walter S. Weeks,
author of:
"Ventilation of Mines" - 1926.
Prof. of Mining, UC Berkeley,
1915 - 1946

Sewell, Chile

Sept. 15, 1944

Dear Mr. Weeks:

Sorry to be so slow writing you, but I think now I can answer most of the questions you had about Braden when we left the States. I am enclosing the answers to a questionaire which some of the fellows sent me. These may give you some idea of conditions here. I would like to answer any more questions you may have, and I hope you will write me if you think of any.

MacDonald and I are both shifting now, and have about 100 men to look out for. We happen to be on the same level, so we see each other at beginning or end of shift. Thurban finally arrived here, and is now finishing up his "practicante" period. There are a great many men here from California. You may remember Frank Lewis, Bob Haldeman, and George Beinhorn. Beinhorn graduated with my older brother. The new General Manager, F.E. Turton, also from Cal, must have graduated between 1910 and 1915. Charlie Roberts left about three months ago, and is reportedly mining in Ecuador now.

← 7 Cal. Grads

Conditions in the mine are relatively good except for ventilation. However, there is a big project under way now which should improve things if it is ever finished. The plan calls for two Jeffreys Propeller fans, each with a capacity of 150,000 cu ft/min and giving a water gauge of about 5". They are trying to make calculations without valid data on the fans, and the chief engineer who does all the figuring has never studied ventilation. He borrowed my 105 notes to try to learn something from them too. We will probably end up with some ventilation, but I wonder how much and how efficient it will be.

← Mine Vent.

There is some hunting and fishing here, and the fishing in the south of Chile is supposed to be excellent. There is a bird here called a perdiz, which is a small partridge. There are also wild pigeons and doves. In the high mountains there are guanacos and vicunas, both relatives of the llama. The guanaco is about like a large deer, and the vicuna like a sheep or goat. I hope to make a trip through the mountains to Argentina, but must save up a full two week vacation for this.

I understand from Mr. York that you have been taking a vacation this semester, and I hope you have been having good luck with your fishing and hunting. Please let me know if there is anything I can do for you done here, and please say hello to Mrs. Weeks for me.

Sincerely,

John Reed

By Walter S. Weeks in 1926

the fans. If a fire occurred and the smoke reached the pump station, it would be necessary for them to shut down the fan, close the door to the pump station, and wait for orders. If the order came to reverse, they could do so and remain in the pump station. If the order came to establish ventilation in the usual direction, it would be impossible for them to escape if this were done before they left the mine.

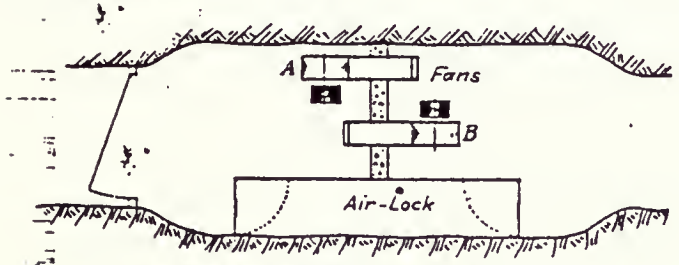

FIG. 109.—Reversible system with remote control (plan).

The difficulty was solved by using two fans facing in opposite directions as shown in Fig. 109. The duct from each fan was equipped with a counterbalanced gate which could be locked by a latch operated by a solenoid as shown in Fig. 110. The solenoid on fan *A* was operated by the line current of the motor on fan *B* and *vice versa*. The motors were equipped with automatic starters operated from the surface and underground.

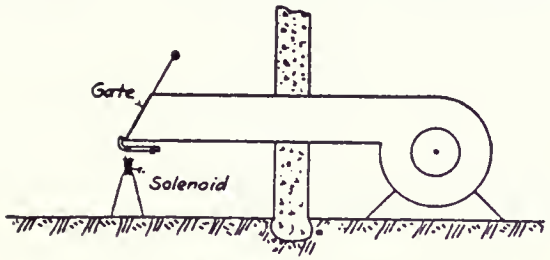

FIG. 110.—Automatic gate on fan (vertical section).

Either fan could be started from the surface. The air pressure from the running fan opened its gate; and the current from the motor of the running fan locked the gate on the other fan.

An underground fan may be supplemented with surface fans for control in case of fire. A blowing fan can be placed at each shaft with the ducts entering the shaft below the collar. In

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Emphasis in George Reed's volume, re. 1936, and well before the Fire in 1945.

case of a fire either shaft can be bulkheaded and the fan started, putting that shaft under pressure. Underground fans can be stopped by throwing off the power. Stopping a fan and bulkheading the shafts do not stop air currents within the mine. The mine becomes a little world of itself with its own natural ventilation, and smoke from a fire may take all sorts of unguessed paths. The fan may be stopped for a time when smoke is discovered, but as soon as decision is reached as to which shaft is to be the exit, this shaft should be placed at the higher pressure and so maintained until the men are out. The actual amount of air circulating may be controlled by throttling at the fan or at the shaft collar.

It is well to equip all fans with two starters because a worn starter may fail.

Surface fans should be in a fireproof housing and coal-mine fans should be equipped with explosion doors.

Meetings of the staff should be held and hypothetical fires should be kindled in all parts of the mine and the exact procedure discussed. It is well to check the discussions by studying the air currents. An official who understands the subject, and with authority to act, should always be at the mine for, if special control is necessary, it should be exercised as soon as conditions underground are known.

Important

Shift bosses should be informed of what to expect from the ventilating current under different conditions.

Ventilation is often complicated by many exits or by special conditions in the mine, such as an old fire or an area in which gases are given off. Whatever be the conditions, the operator must put his mine and his ventilation system in such shape that if a fire occurs in any part of the mine, the men can escape to a safe exit, the air pressure in which can be made higher than the region in which smoke or gases exist.

Auxiliary Fans for Fire Fighting.—Small portable fans are sometimes used for fire fighting to drive back gases if the fire zone has a vent. Temporary air locks are built in a drift. The fan is placed outside and the air is conducted through the lock in a pipe.

Mineral Fires.—A careful study of mineral fires was made at the Huelva Pyrites Mine.[1] The conclusions were that the fire

[1] BROWN, A. O., "Mineral Fires in the Huelva Pyrites Mine," *Trans. Inst.*

By Walter S. Weeks in 1926

the fans. If a fire occurred and the smoke reached the pump station, it would be necessary for them to shut down the fan, close the door to the pump station, and wait for orders. If the order came to reverse, they could do so and remain in the pump station. If the order came to establish ventilation in the usual direction, it would be impossible for them to escape if this were done before they left the mine.

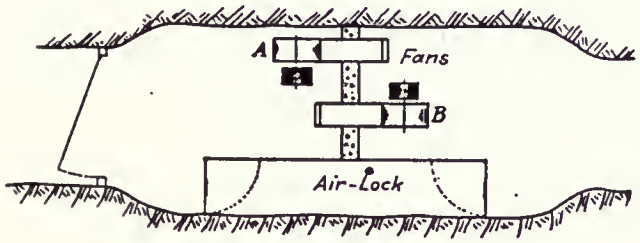

FIG. 109.—Reversible system with remote control (plan).

The difficulty was solved by using two fans facing in opposite directions as shown in Fig. 109. The duct from each fan was equipped with a counterbalanced gate which could be locked by a latch operated by a solenoid as shown in Fig. 110. The solenoid on fan *A* was operated by the line current of the motor on fan *B* and *vice versa*. The motors were equipped with automatic starters operated from the surface and underground.

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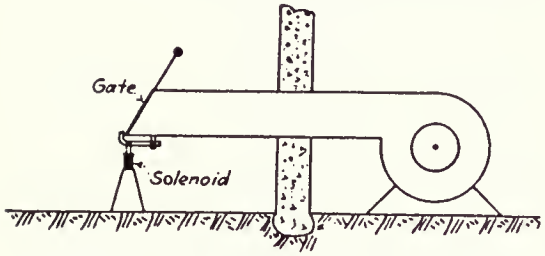

FIG. 110.—Automatic gate on fan (vertical section).

Either fan could be started from the surface. The air pressure from the running fan opened its gate; and the current from the motor of the running fan locked the gate on the other fan.

An underground fan may be supplemented with surface fans for control in case of fire. A blowing fan can be placed at each shaft with the ducts entering the shaft below the collar. In

Emphasis in John Reed's volume, re. 1943, but added during teaching after the Fire.

case of a fire either shaft can be bulkheaded and the fan started, putting that shaft under pressure. Underground fans can be stopped by throwing off the power. Stopping a fan and bulkheading the shafts do not stop air currents within the mine. The mine becomes a little world of itself with its own natural ventilation, and smoke from a fire may take all sorts of unguessed paths. The fan may be stopped for a time when smoke is discovered, but as soon as decision is reached as to which shaft is to be the exit, this shaft should be placed at the higher pressure and so maintained until the men are out. The actual amount of air circulating may be controlled by throttling at the fan or at the shaft collar.

It is well to equip all fans with two starters because a worn starter may fail.

Surface fans should be in a fireproof housing and coal-mine fans should be equipped with explosion doors.

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[1] BROWN, A. O., "Mineral Fires in the Huelva Pyrites Mine," *Trans. Inst. Mining Met. Eng.* (London), vol. 64 (1922–1923).

APPENDIX C

1261 Campus Drive
Berkeley 8, Calif.

June 24, 1952

Dr. J.R. Van Pelt, President
Montana School of Mines
Butte, Montana

Dear Dr. Van Pelt:

As discussed with you during your visit to Berkeley this month, I shall finish work for the degree of Master of Science in Mining in September 1952. My thesis is entitled "An Analysis of Mine Opening Failure By Means of Models". I should like to continue my work on the general subject of mine opening failure, support, and efficiency, with the hope that this will lead to a degree of Doctor of Philosophy in Mining. I believe that I am well qualified to do research in this field by my technical training plus six years' practical experience at a large mining operation employing the block caving method.

My experiments to date have been with mine models, and the results have been helpful in determining the actual manner of failure of a mine opening in massive rocks. With recent literature on roof bolting, guniting, and grouting in mind, I conceived the idea of supporting a mine opening by strengthening the rock section around the opening instead of placing a supporting structure within the opening in the conventional way. Preliminary tests of this idea have now been made in models, and while the results are largely qualitative with present equipment, they are very encouraging. It is felt that further work with the method could best be done on full scale mine openings under actual conditions, and a mine using the block caving method appears to offer the most uniform and controlled conditions possible.

With the knowledge that the Anaconda Company is beginning block caving operations at Butte, and is interested in mining research, it has occurred to me that this Company might be willing to cooperate by making an experimental installation in an active mining area. The opening could be standard size or somewhat smaller, and be driven in the conventional way. It is visualized as being a normal draw control drift directly beneath the undercut level, and would be expected to fulfill its normal functions. The equipment and materials necessary are all standard types, and would be on hand at any large mine or easily available commercially. Material costs should be of the same order as initial timbering costs in a drift supported in the conventional way.

I firmly believe that this concept of ground support can be of immediate practical value to the mining industry, and careful measurements and observations taken during an actual test could be of great value in technical mining research as well.

An arrangement at your institution whereby I might teach a light schedule of courses while continuing my research would be most attractive to me, and I hope such a plan can be worked out.

Yours very sincerely,

OPENING REINFORCEMENT

In many mines, if not most mines, the rock surrounding the openings is stronger than massive concrete. The United States Bureau of Mines has measured the physical properties of a wide range of mine rocks. (Bib. 30,57,58) Tests on 191 typical mine rocks gave compressive strengths ranging from about 2,500 p.s.i. to nearly 100,000 p.s.i., and averaging 30,600 p.s.i. The strength of normal concrete ranges from about 2,000 to 5,000 p.s.i. Therefore, it is apparent that the extra rock broken out to make room for conventional mine support sets is often far stronger than the material with which it is replaced. Instead of making a larger opening to give room for internal supports, the smallest usable opening should be driven with care so as not to damage the surrounding rock. If the opening is not then self-supporting, the rock around the opening should be reinforced the necessary small increment to make it so.

To investigate the possibility of reinforcing the rock section around an opening, models R-12 and R-14 were prepared and tested. The wire reinforcements were placed to simulate roof bolts. Rock bolts is here suggested as a general name for such roof bolts used anywhere in the opening periphery, rather than in the roof alone. The hooks provided anchorage comparable to the wedges that anchor rock bolts. The wire used for the reinforcements is a special barbed type used by cobblers in so-called nailing or stitching machines. The reinforcements were

made of a length to represent the longest rock bolt that could be placed from the given opening in the given position. The opening in model R-12 represents a drift about 8 feet square with reinforcements placed on 4-foot centers. In actual practice, each reinforcement would be replaced by two rock bolts, and these could be placed on 2-foot centers and staggered, first to one side and then to the other. For convenience in casting, the reinforcements were prepared in assemblies as pictured in Figure 7a. This was done with the aid of the jig shown in Figure 8. The white strip is a one-fourth inch ribbon of very thin cardboard. The wires are glued to the strip by one drop of Duco cement at their point of contact. Once prepared, the ribbon with its wires was stuck in the heavy grease with which the form was coated, and light thread was used to lash the assemblies to the form. Nothing stronger than the thin cardboard could be used to make the assemblies, because the model must be sliced with the saw after loading.

Models R-12 were cast with a 1-inch square opening reinforced every one-half inch thru the entire block. The loading pressure required to cause this reinforced opening to fail was 28 percent higher than that required on an un-reinforced opening of the same size. Figures 18 and 19 show sections thru model R-12-2 after loading.

Models R-14, with the short sides of a rectangular opening reinforced, were cast to test the idea of reinforcing the critical portions of a section not equally stable in all directions. The loading pressure required to cause failure of the reinforced opening was 23 percent higher

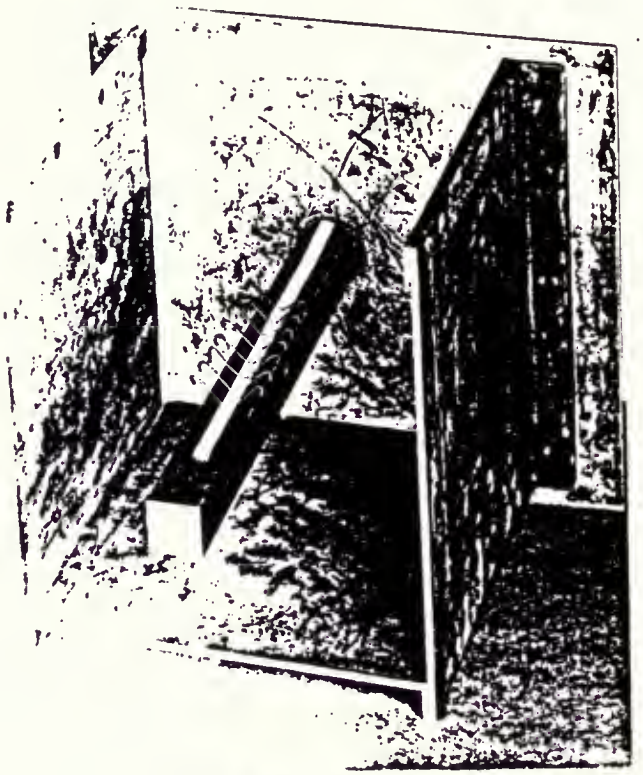
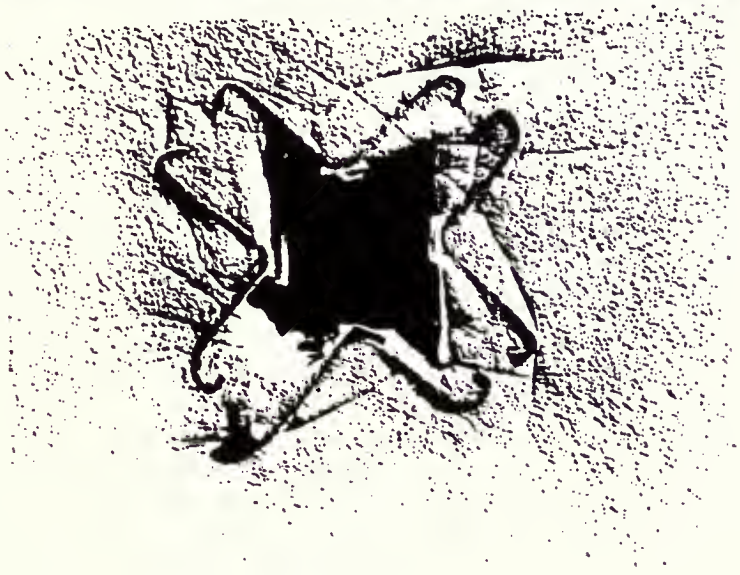


Figure 2.

Cubic Model Mold

Note: One partial reinforcement assembly in place for illustration



R 12 2

Figure 19.

Model Type R-12

Reinforcement exposed, opening 1-inch square reinforced on 0.5-inch centers

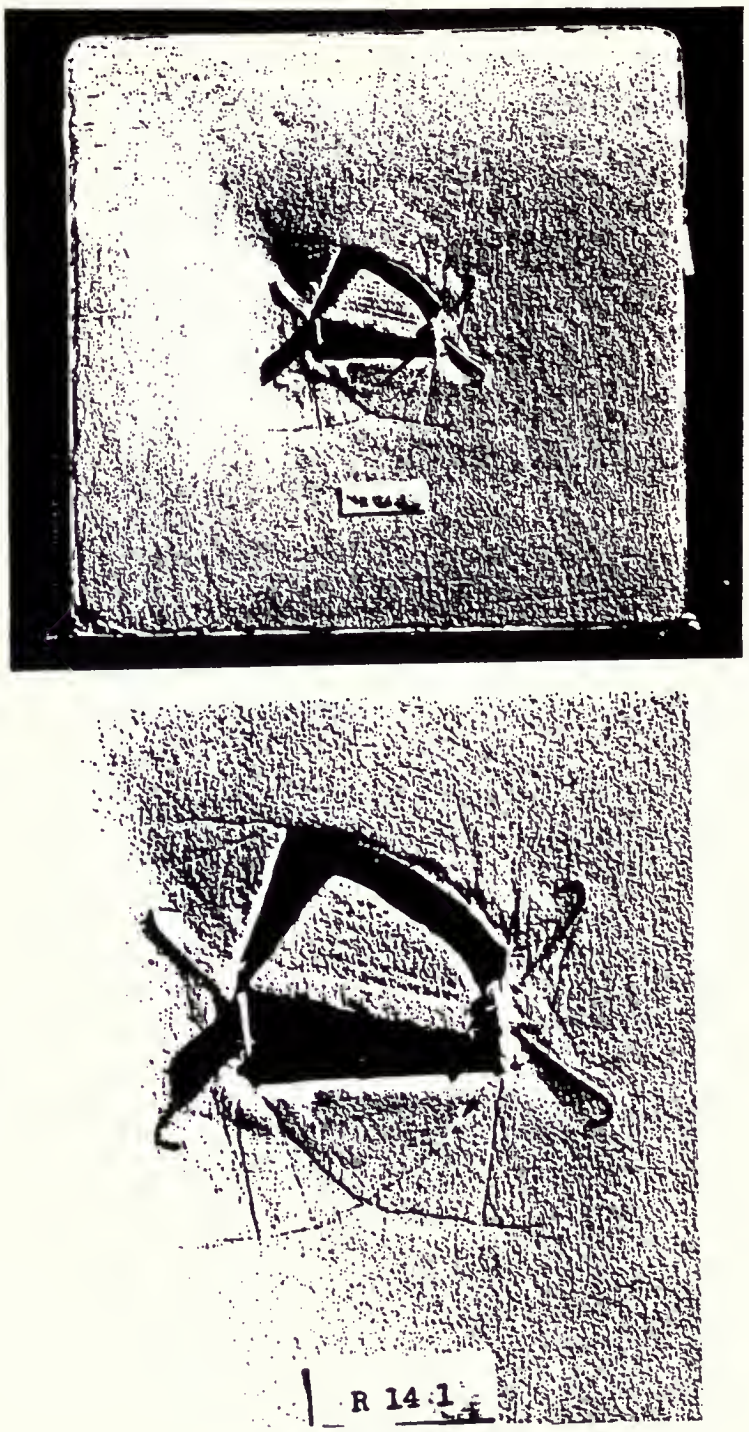


Figure 21b.

Model Type R-14

Reinforcement exposed, opening 0.75 by 1.5 inches, reinforced on 0.5-inch centers

than that required on the identical un-reinforced opening tested in models R-9 (see Figure 15). Figures 21a and 21b show sections thru block R-14-1 after loading.

The analogy between rock bolts and prestressed concrete should be described here. In ordinary reinforced concrete, the steel cannot be effective until the concrete in that part of the section has failed. In prestressed concrete, the steel is working to a high percentage of its capacity even before loading begins, and it adds its strength to that of the concrete. Rock bolts should act like the steel in prestressed concrete, adding their increment of strength to the inherent strength of the rock before appreciable failure occurs. Because there was no way to prestress the wires in the models, they acted like the steel in ordinary reinforced concrete.* Therefore it should be understood that rock bolts used in the same way in actual practice should prove much more effective in reinforcing mine openings than indicated by the model tests.

* or simple untensioned grouted rebar, (1990)

CONCLUSIONS

The results of this investigation substantiate mathematical and photoelastic studies in demonstrating that under hydrostatic loading, mine openings will fail in shear. The experimental results also agree with theoretical analysis as to where initial failure will occur due to stress concentration on certain openings. However, there is a distinct difference between test results and theoretical analysis as to the relative stability of various sizes and shapes of openings in a brittle material when loaded hydrostatically to failure.

As described in the section on the factors controlling opening stability, under shape and size of opening, this difference can be explained in the test results on the models by considering the probability of failure as well as the calculated maximum stresses on the openings.

If the probability of failure has such an important control on the stability of a nearly perfect cast opening in a relatively isotropic model material, then it certainly must be the major controlling factor on the stability of a prototype mine opening; because the rock is never isotropic, the opening is usually highly irregular, and, because of blasting, it is surrounded invariably by a zone of shattered material with a high failure-probability.

The importance of making mine openings small, with regular cross section, and without damaging the remaining rock section, has been much neglected by mine operators.

The results of this investigation demonstrate that these factors exert the major control on the stability of the resultant opening. Artificial opening support is expensive and troublesome. Therefore, it is important to design the opening carefully as to size and shape for maximum stability, and then exert every effort to drive the opening in such manner as to preserve the maximum possible of the inherent strength of the material. A great deal can be accomplished by careful design of drill rounds and blasting technique. More trim holes, of smaller diameter, and loaded lightly with a low-grade bulky explosive will result in the minimum of damage to the remaining rock section.

The ideal method of driving an opening would be by boring or cutting out the rock without blasting. Shafts drilled by shot drills are an example, and have proved practical. (Bib. 40,41) Unfortunately, shot drills will drill only near-vertical openings, and a machine to drill or cut a horizontal opening of usable size in hard rock remains to be developed, although holes 21 inches in diameter have been drilled by diamond drill. (Bib. 28) A machine has also been described by Lewis (Bib. 23a), which was used to drive tunnels in chalk at Fort Randall Dam in South Dakota. An opening driven by such means would not need to be as large as conventional mine openings because of its smooth self-supporting nature. A round opening four or five feet in diameter might be quite effective. Scrapers and conveyors are capable of moving large tonnages thru openings of small cross section. The development of a machine to bore or cut horizontal mine openings is worthy of the full support and interest of the mining industry.

P.O.Box 704
Flat River, Mo.
February 16, 1957

Dr. Charles L. Lowman
2417 S. Hope St.
Los Angeles 7, Calif.

Dear Dr. Lowman:

Thanks for your letters in answer to our last two Christmas messages, and we are glad you have enjoyed our cards and news letters. This letter has been in the writing for several months, and now I shall try to get it typed finally, and off to you.

When I talked with you in June 1955, on our way here, you asked me to write you a short account of my bout with polio, and subsequent activities. I have been very slow in doing this, but hope that it may still be of interest to you, and perhaps a source of encouragement to others.

As you know, for some six years prior to my illness in 1950 ~~(xxxx)~~, I had been working as a mining and construction engineer in Chile. On January 2, 1950, my wife and I accompanied a group going fishing in the mountains. The trip normally required a three-hour horseback ride over rough trails. We arrived at the stream on Monday, and the horses were to return for us on Friday.

Tuesday, we had a long day's fishing and swimming in the cold stream. That night I was unusually tired, and toward morning was awakened by a stiff soreness in my neck. The next two days I had all the usual polio symptoms: Nausea, weakness, and extreme headache in the back of the head and neck, especially upon bending over. By Friday morning, I was still able to walk, but was so weak that I couldn't put on my heavy wool socks and boots because my hands had no grip. When the horses arrived at noon, I had to be lifted onto a horse, but once up I could manage to stay on un-aided. The ride home took six hours, with many stops for rest. At the end, I was lifted from the horse and half carried ~~fx~~ into the house. If we had known I had polio, and the susceptability of fatigued muscles to permanent paralysis, I could have been carried home on a stretcher, and very likely would have had little permanent incapacity. As it was, I had only a vague suspicion, and did not voice it. The first doctor's diagnosis Friday evening was "sunstroke". This is in itself a good measure of the caliber of medical care we had available to us.

During the next day or two, I became almost completely paralysed, except for my left hand and the biceps in my arms. Although my breathing became very weak and shallow, I never required an iron lung. There were none in Chile at the time if I had. After several days, the local doctors plus a specialist from Santiago identified my illness as one effecting the nerves and muscles, but never called it polio. This in spite of an epidemic of polio 100 miles away in Santiago at that time!

After 5 weeks, still in our own home, and with my wife and a maid trying to care for me; I was still almost completely paralysed and growing very weak. My weight dropped from 145 to about 95 pounds. At this point, Dr. Nathanial Greenfield and two physical therapists from New York, who were instructing on post-polio care in Santiago, were brought to examine me. My case was immediately diagnosed as polio, and the therapists checked my muscles and instructed my wife in applying steam packs and the necessary steps towards

regaining the full range of motion in all my muscles, etc. Two weeks later, they returned hoping to find sufficient improvement to permit my transfer to the States in a wheelchair. Instead, they found me even weaker, and my left leg was showing signs of bad circulation and swelling. This was a Friday, and Dr. Greenfield recommended I be transferred to the States immediately. Eileen managed to get plane space, passports, etc., cleared so fast we left Santiago the following Wednesday with me on a stretcher.

I can never say adequately what a tremendous relief it was to both of us to land in Los Angeles and finally know that people we had faith in were taking over all the details. Then, at last, we felt we had the best available, and time and the Almighty would do the rest. I recall you had me walking in the warm pool within a week, and what a wonderful lift and hopefulness that gave me.

You are familiar with the rest of my progress at Orthopedic Hospital. There was surgery on my right hand in May or June by Dr. Boyes, and I was an out-patient by August, I believe. The two long-leg braces were dropped along the road, and finally you did the muscle transplant on my left leg about Dec. 1, 1950.

By this time it was clear I would always have some disability, and that I would never again be able to do the more active and rigerous jobs in mining. Therefore, I realized I shold re-design my life and try to prepare myself for teaching, or other work connected with mining, but requiring more thinking and less physical work and agility. To this end, I enrolled at UCLA in February 1951 as a graduate student in Geology. About two weeks later, I received an offer from the University of California at Berkeley, and moved there as an Instructor in Mining.

My status with the Company in Chile had never been really settled, and we had left our house there untouched. Therefore, in June 1951, I flew there alone to settle the matter in person. The Management decided I should not be re-employed unless I were 100% recovered, so I sold out our furniture, etc., and returned home with our personal belongings by freighter.

Back at the University in Berkeley, I set my sights on the highest possible degree I could obtain in Mining Engineering. In doing this, I felt I could always count on a good job with a University, but I also hoped that eventually the Mining Industry would recognize its need for research, and that I would then be ready to take an important part. Perhaps I should emphasize here the very real drive I felt inside me from the beginning to again make myself useful. I enjoyed the Occupational Therapy work for that reason. Making the key cases, wallets, picture frames, weaving cloth, etc., were all fun; but above all, they were also <u>useful</u>, and that made me feel better inside.

When I was very sick, and the Company was refusing to pay my medical bills and re-hire me, things looked pretty rough. I wondered what sort of reward was this, after a good record in school and 6 years of dependable service. Later, at the University, the value of my undergraduate record of good grades and the experience made itself apparent. Part time teaching and research positions helped our finances during two years, and scholarships took care of the other two. I received the M.S. in Mining in

September 1952, and then started on a Ph.D. Mine would be the first doctorate for a thesis in Mining Engineering in the history of the University of California, and many people thought it either wasn't worth the effort in the subject of mining, or else that I would be unable to find an acceptable problem for a thesis. By June 1955, the degree was granted, and my hopes materialized in an opportunity to head a brand new mine research department for one of the Country's larger mining companies.

I should here like to comment on something I consider very important to those planning to prepare for future jobs, etc., and especially to those, like myself, physically handicapped to varying degrees. I believe one should choose not just the line of work most interesting to him, but also one in which there is not already a surplus of qualified people. Then prepare one-self by study and training to the very limit of ones ability.

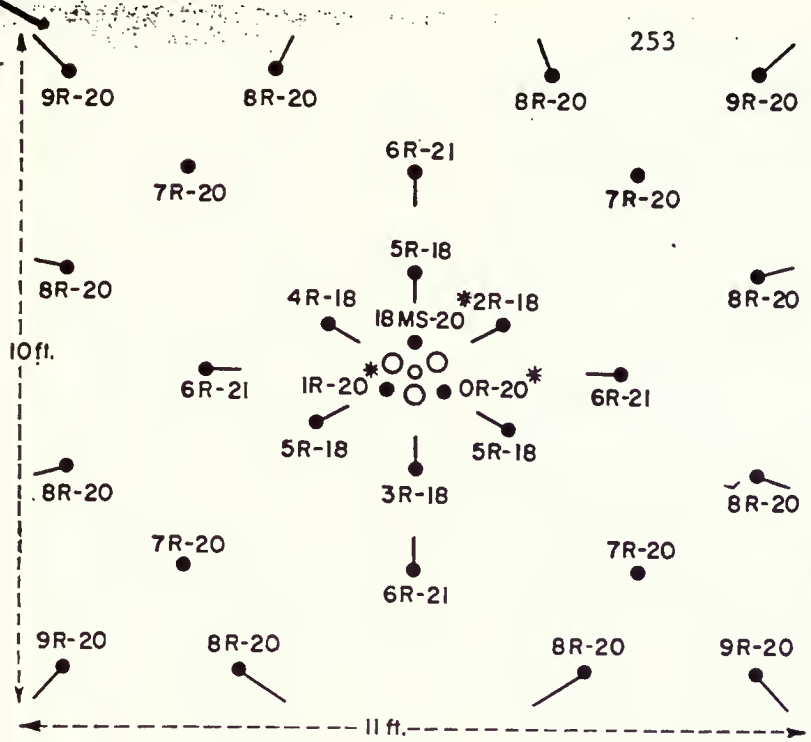
In my own case, I was fully qualified by education and experience for this research position, but it was initially refused me on the basis of a physical examination. In order to demonstrate my own confidence in my ability to do the job without endangering myself or others, I offered to take the position on a trial basis for one year, at which time the Company would decide if it were to be permanent. After a year and a half, my confidence has been justified. I have had no great difficulty in getting around anywhere I had to go in the mines, and the work of the research department is progressing as well as can be expected from a new research effort.

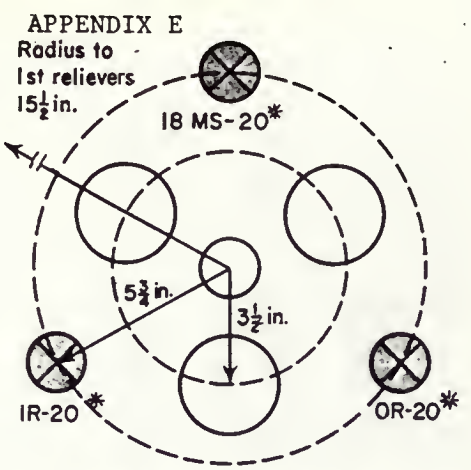
Before I close, I must emphasize very strongly the great debt I feel I owe: 1st, to my Gracious Lord for keeping me alive and giving me the faith and determination to persevere; 2nd, to you and all like you at Orthopedic who give their dedicated knowledge and service to those who need it so badly; and 3rd, to all my wonderful family who encouraged and helped me, and who kept their chins up when I was having plenty of trouble with my own. I can honestly look back now, and feel that my contracting polio in Chile was not really bad. It was the only way God could get me back up here doing the job he had for me, and I feel that I am infinitely better off now than I have ever been before. I must work hard now to justify the Lord's grace, and the faith and help invested in my future by so many wonderful people.

I trust this finds all well with you and your family, and all the Good Folks at Orthopedic Hospital.

Con mis sinceros saludos,

Jack J. Reid





Drilling Data: Three 3 in. and four 1⅜ in. cut holes, plus 26-1⅜ in. holes; all 12 ft deep.

Blasting Data: Unblackened holes empty; "6R-18" indicates No. 6 Regular delay detonator with 18- 1x8-in. sticks of Gelamite No. 2 (Hercules 40%, velocity 11,500 fps); "18MS" indicates No. 18 (450 ms) DuPont millisecond delay detonator; "*" indicates explosive is DuPont Lump Coal CC (vel. 5,500 fps) in 1¼x8-in. sticks tamped lightly.

RECENT result of mining research at St. Joseph Lead Co. is this drift round which pulls 11 ft.

How St. Joe Uses Mining Research

JOHN J. REED
RICHARD L. BULLOCK
JOSEPH J. YANCIK

MINING RESEARCH is not new with St. Joseph Lead Co. Back as far as World War I, the search began for an efficient mechanical loader. By 1925 this resulted in the St. Joe shovel[1] —so successful a design that about 50 of these machines, acquired during the next few years, are still in regular efficient service after 30 years. Much has been done on drill and bit testing, and on developing drill rounds for column mounted machines and for jumbos.[2] Shaft sinking has been highly developed in southeast Missouri, both as to efficiency and safety[3]. And it was here that roof bolting was born, some 15 to 20 years before its rapid growth in coal fields.[4]

Department Setup in 1955

Essentially this testing and development was on a practical basis; and, although much of it had been successful in the past, it was decided in 1955 that solving many of the future problems would need a more fundamental approach. On that basis a new mine research department was organized.

Projects under investigation by the present mine research department can be divided into two general classifications. One group of problems lends itself to relatively rapid, independent solutions. The other group requires long range fundamental studies and the relatively long term solution of many complicated and interrelated problems.

Drifting Efficiency Is Studied

The first assignment—an example of the first classification—was development of an improved drifting cycle. The present drift crew consists of two men on contract who use air feed drills mounted on columns. Their cycle of clean, drill, and blast is completed every shift, and average advance in a 10x12 ft drift is 5 to 6 ft per shift, using a pyramid cut. Many attempts have been made in past years to develop a successful burn or shatter-type cut for Lead Belt dolomite, which would permit breaking a deeper drift round. No consistent success was ever achieved because the broken rock always "froze" or recompacted in the cut, and the rest of the round could not break. It was apparent then, that although drilling, loading, and haulage would probably all need improvement before a long drift round could become a reality, the single truly critical requirement was a consistently successful deep cut.

Eighteen months of research, testing and development led to a three-large-hole shatter-cut drift round. It was considered acceptable after it was tried 25 times, drilled 12 ft deep, and averaged 11 ft of advance.[5] An attempt to apply a somewhat shortened version of this round using jack-legs led to the development of a simple drilling jig, which aided the accurate drilling of the cut pattern. It was finally concluded, however, that there was too much drilling for two men with jack-legs in this size and depth of round, and a jumbo unit was the only logical answer.

Now, after another year of development, a two-man drift jumbo has been built with three booms and machines capable of drilling the shatter-cut round 8 to 10 ft deep in about 2½ hours. With bigger drills and longer feeds, the same rig should drill 10 to 12 ft in the same time.

Other Projects Aid Drifting

When fundamental investigation of the cut had progressed to the point

Dr. Reed is head mine research engineer and Messrs. Bullock and Yancik are mine research engineers for St. Joseph Lead Co., Bonne Terre, Missouri.

where ultimate success was assured, three projects of a more applied nature were initiated to solve related problems of a greatly improved drifting cycle. One is development of a drifting jumbo mentioned above. Ultimate goal of this project is a diesel powered unit mounting 3-in. machines on 12-ft feeds, and preferably adapted to drilling in both drifts and production stopes.

Second related project was the test of ten standard percussion rock drills with different combinations of steel and bits. This resulted in tabulated ratings as to efficiency and penetration rates. The work emphasized importance of hole size, air pressure and consumption, and steel size and length. It provides a valuable ready reference from which to choose best combination of drill, steel and bit to meet a given set of conditions.

Third related project is an investigation of rotary-percussion drilling. This system of drilling holds great promise for the future in that it should provide faster, more efficient drilling with greatly improved steel life in our medium-hard, non-abrasive dolomite.

Pillar Recovery Is Tackled

Second major assignment of St. Joseph Lead Co.'s mine research department is one which requires long-range fundamental studies—developing way to recover pillars in old mines and to increase extraction in new mines. It is estimated that 10-15% of original ore has been left as pillars since mining began in 1864. This now represents an attractive ore reserve, but its recovery is complicated by towns and company plants over much of the mined area.

One project in attacking the problem is a series of case history studies. Regular periodic observations and measurements are made on several large caved areas in the mines. Similar investigations are made in active stopes to study degree and progress of convergence during mining.

Another fundamental project concerns suitable instrumentation for rock mechanics studies. This has involved design and development or use of a convergence extensometer, roof bolt compression pads, a 20-in. Whittemore strain gage, microseismic equipment, borehole load cells, Valore gages, and sonic velocity determinations. At present, a project is being set up to study physical properties of various rock zones in an effort to correlate roof behavior in different mines with the type of roof rock in each case. Instrument development is a major problem in the general field of rock mechanics, because very little suitable equipment is available "off the shelf", and almost every item must be hand made to fit the particular application.

Knowledge and experience gained from case history studies, and developing usable instruments, has led to a first attempt at pillar recovery. Plan being followed involves greatly improved roof bolting techniques and application of systematic rather than casual bolting. By systematic bolting on 4 and 5-ft centers, spans up to 100 ft have been held under normally bad roof conditions, while pillars were blasted and the ore loaded. Convergence measurements and micro-seismic records have been the principal means of assuring safety during these operations. While this plan of pillar recovery has very definite limitations, there are many areas where it can be applied, and its costs appear competitive with those of mining new ore. It is hoped that continued studies will lead to methods for complete removal of pillars over large areas, perhaps with delayed tailings fill to prevent excessive surface subsidence.

Over the past 20 years, a considerable number of massive concrete pillars up to 12 ft in diameter and 50 ft tall have been built in the Lead Belt mines. Most of these were built to safeguard important installations, but some were supposed to replace rich ore pillars which were then to be removed. In order for a pillar of this size to carry a load approaching its safe capacity it must be shortened on the order of ¼ in. Under normal conditions this can only happen if the roof comes down by that amount, and experience and observation indicate that before this happens the roof usually breaks up and falls around the pillars without ever causing failure in the pillars themselves.

In an effort to improve this situation studies are being made to develop a system of pre-loading large pillars to a relatively high proportion of their ultimate capacity. In addition to preventing further deformation of the roof this system should actually tend to reduce the already existing strain in the roof and adjacent pillars. Application of flat jacks injected with grout is being studied as a possible solution.

Grouting Is Being Systematized

Grouting itself is another research subject. It has always been of some importance in southeast Missouri mining because the ground is cut by many fractures and solution channels. However, it has never become a continuous part of operations, and therefore experienced crews are always scattered and lost between jobs. Thus there has been very little accumulation of experience and data on a continuing basis. Studies are being made to improve this situation. All available literature on grouting is searched and digested. This is supplemented by laboratory tests and case studies of grouting jobs in the mines. It is hoped that this will result in a sort of operating handbook on grouting to help new crews and in selection of suitable grouting materials and equipment to meet varying conditions of each application.

To Encourage Others

It is hoped that this brief outline of the St. Joseph Lead Co.'s mine research program will prove of interest to others in the mining industry and will stimulate the development of similar efforts elsewhere. There is an urgent need to raise mining from the level of an art towards that of a science. A greatly expanded effort on fundamental and applied research plus a more active interchange of ideas between organizations and branches of engineering should do much to meet this challenge.

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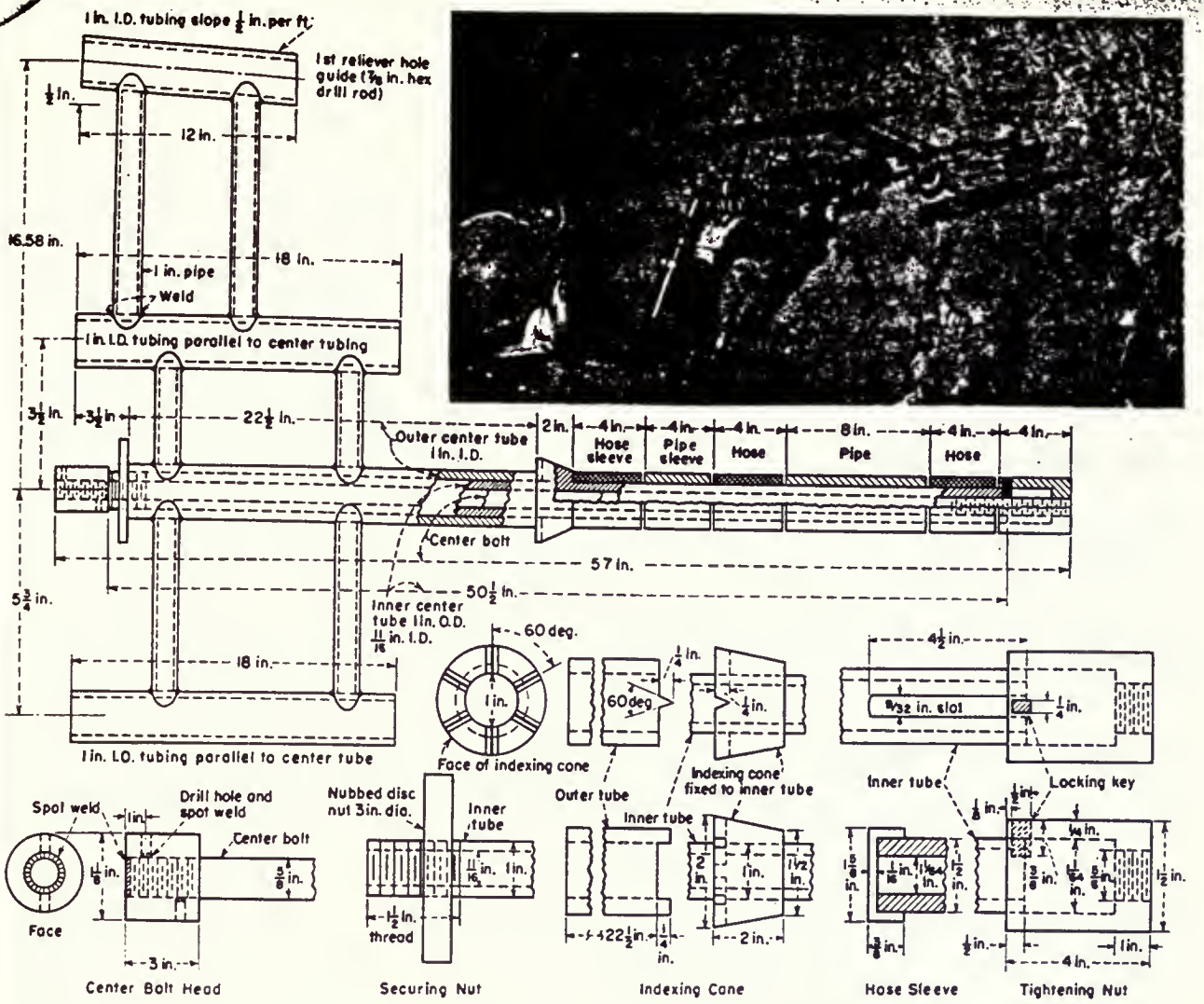

Note: Schematic Sketch, not to scale

RIGID FRAME of pipe is built on outer center tube. When securing nut is loose, frame can rotate about inner center tube; but when nut is tight, teeth on outer center tube fit in notches on indexing cone and prevent rotation. Inner tube is held secure in hole by expansion of rubber hose sections, effected by turning center bolt and drawing up tightening nut.

St. Joe Jig Aids Airleg Drilling of Long Cut

SIMPLE HOLE-LAYOUT JIG was devised for airleg drilling of deep "shatter" (burn) cut at St. Joseph Lead Co., Bonne Terre, Mo. Mine research group—Dr. John J. Reed, head; Richard L. Bullock and Joseph J. Yancik, engineers—developed both jig and cut. (Drawing is shown on title page 85.)

Jig is designed to insure correct hole spacing and alignment which are especially critical for efficient long-hole shatter cuts. It is only used for drilling the 30 to 40-in. starter holes. Starter steel is 5-ft, ⅞-in. hex for conical-taper slip-on bit.

To use jig, first step is to drill a 1¾-in. center hole. It should be 36-40 in. deep and as straight as possible. When completed it is washed clean. If any cut holes are to be reamed to larger size later on, this first hole should be angled up slightly to aid flushing of cuttings from the holes.

Second step is to emplace assembled jig. "Stinger" (i.e., long projection which bears short sections of hose) is inserted into center hole up to "indexing cone." Outer hole-guide is oriented to hang vertically below center hole. Then by hammering on head of "center bolt," indexing cone is wedged tightly into collar of drillhole.

Third step is to anchor jig more securely. Head of center bolt is turned with 18 or 24-in. pipe wrench to draw-up "tightening nut" and thereby expand rubber hose sections into tight contact with hole sides. During drilling it may be necessary to retighten occasionally.

Drilling now begins. In this first position, all three hole-guides are used. On completion of the three starter holes, "nubbed wheel" on inner center tube is loosened and guide frame rotated 60 deg so indexing points on outer center tube fit into next pair of vee-slots in indexing cone. Nubbed wheel is tightened and outer hole only is drilled. Frame is rotated another 60 deg for three holes, etc. until entire cut is drilled to starter depth. Jig is then removed by loosening center bolt and withdrawing stinger.

At St. Joe, three large relief holes are completed next. These are first drilled at least 4 in. deeper than final depth (e.g., 12 ft plus 4 in.) with standard bit, after which they are reamed to full size. (e.g., 3 in.) Remainder of starter holes are then extended to full depth. Standard practice of eye-aligning drill using drill steel in adjacent holes is followed. As it is, the first 30-40 in. drilled with jig keeps holes aligned fairly well.

APPENDIX F
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Interviewer, Regional Oral History Office since 1985, specializing in mining history.

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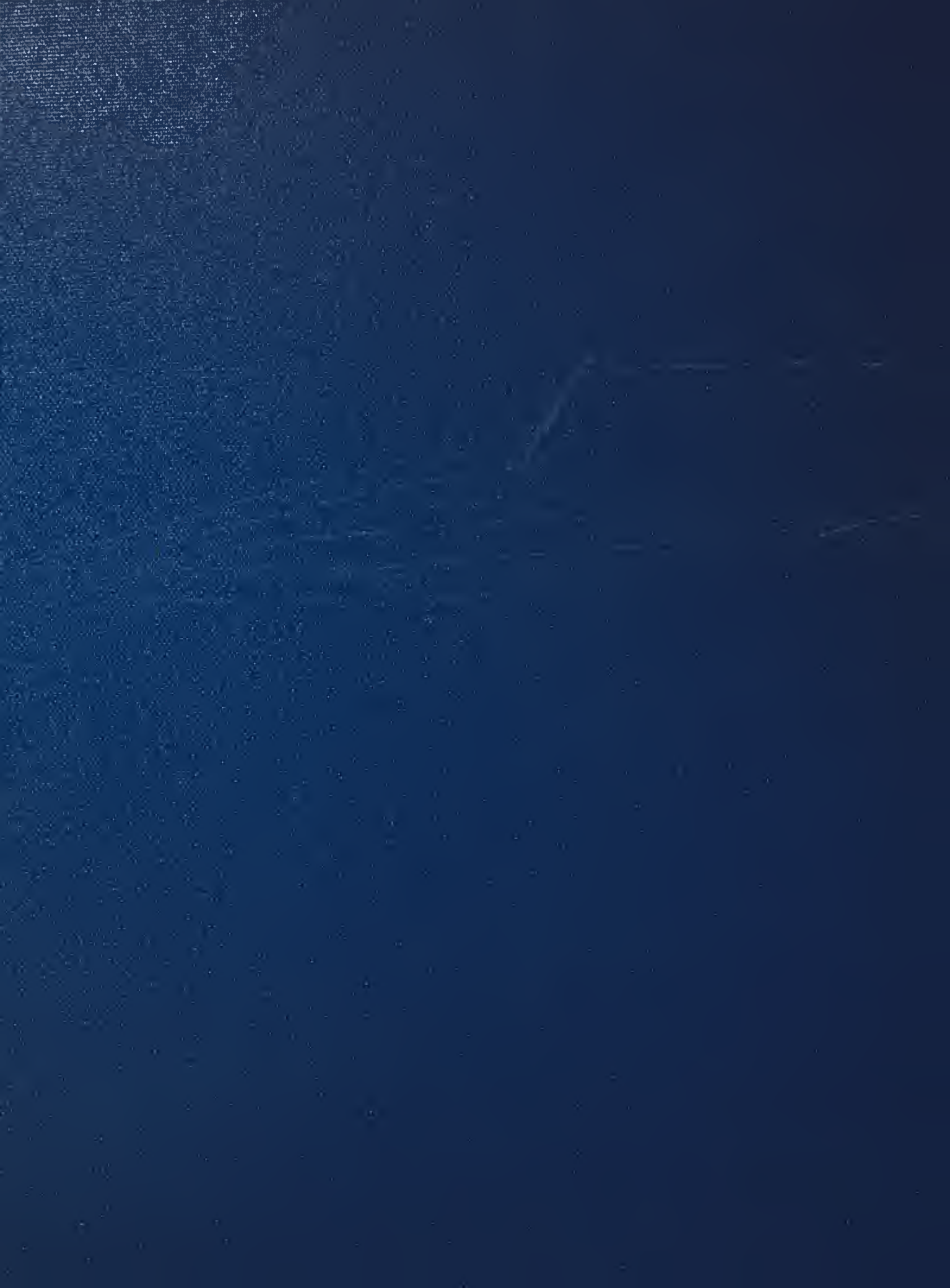
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